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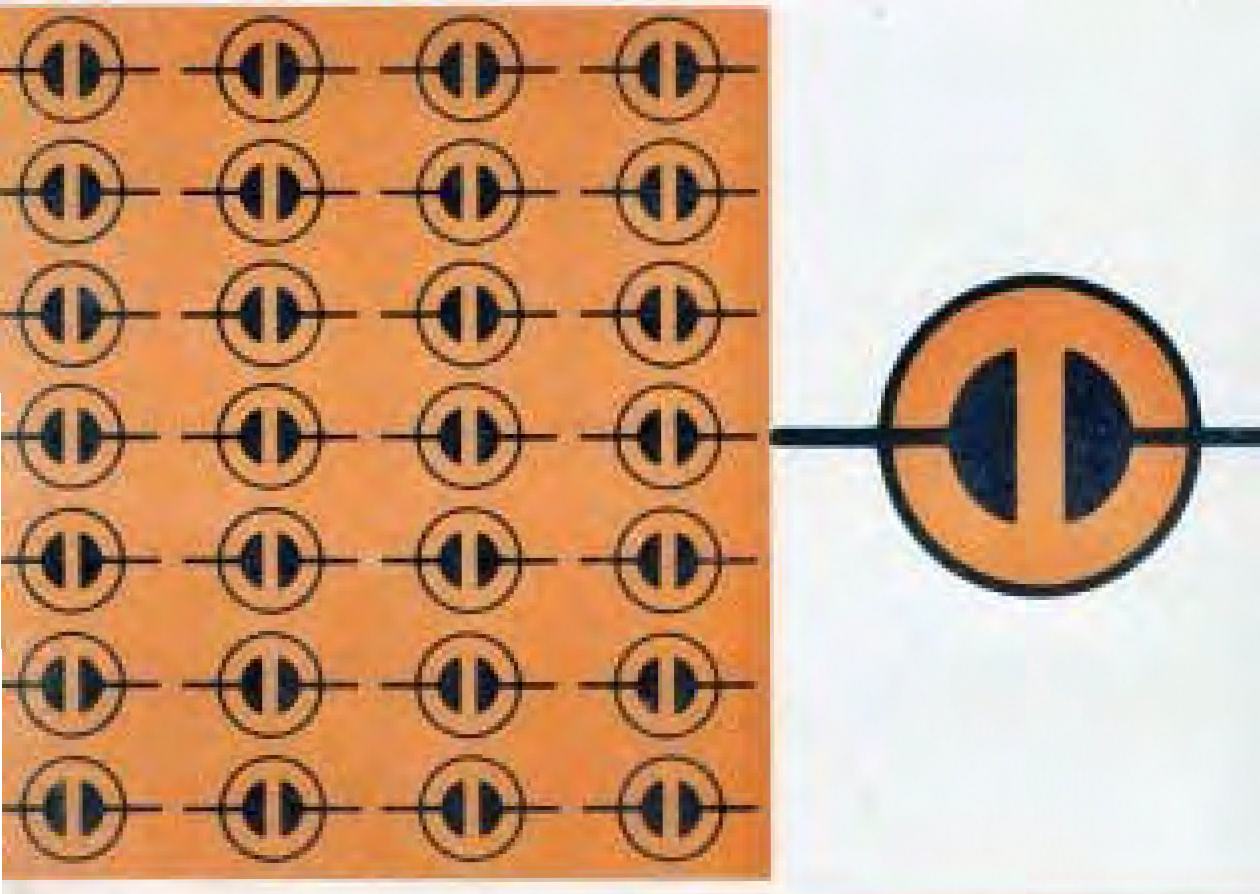
using and understanding miniature NEON LAMPS

by William G. Miller



Using and Understanding MINIATURE NEON LAMPS

By
William G. Miller

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Contents

CHAPTER 1

THE NEON LAMP 7

Basic Operation — Corotrons — Progressive Explanation of Terms — Physical Considerations

CHAPTER 2

INDICATORS 15

Incandescent Versus Neon — Standard Brightness — High Brightness — Ultraviolet — Construction — Practical Indicators

CHAPTER 3

VOLTAGE REGULATORS AND REFERENCES 25

Description — Application — Regular Construction — Circuit Design Considerations — Practical Regulator and Reference Circuits

CHAPTER 4

OSCILLATORS, PULSE GENERATORS, AND FLASHERS . . . 37

Single-Lamp Oscillators — Two-Lamp Multivibrators — Flashers

CHAPTER 5

COMPUTER CIRCUITS 49

Bistable Multivibrator — Monostable Multivibrator — Three-Input *OR* Gate — Three-Input *AND* Gate — Three-Input *MAJORITY* Gate — Design Considerations — Ring Counter — Trigger Circuits — Complete Decade Ring

CHAPTER 6

MISCELLANEOUS CIRCUITS 61

SCR Control — Relay Circuits — Photocell Circuits — Photoconductive Junction Devices — Temperature and Humidity Sensors — Timer Circuits — Touch Control — Audio Switch — Variable Delay Circuit — Overvoltage Circuits

CHAPTER 7

POWER SUPPLIES AND INSTRUMENTS 79

Unregulated 160-Volt Supplies — Regulated Power Supplies — Voltage Calibrators — Transient Voltmeter — Electrician's Friend — High-Energy Detector — A-M Signal Generator

CHAPTER 8

REFERENCE SECTION 93

Light Output — Shunt Capacitance and Internal Resistance — Dri-Film Coating and Leakage — Aging Procedures — Aging Equipment — Neon-Lamp Specification Chart and Numbering Systems — Using the Specification Chart — Testing Guidelines — Specifying Guidelines — Pricing Guidelines — Mounting Considerations — T1 and Ball-End Lamps — T1⅜ Crater-Electrode Lamps

APPENDIX 117

Using the Nomograms.

INDEX 123

Preface

Miniature glow lamps have been in use for many years and are familiar to most readers as indicators and relaxation oscillators. Practically everyone has seen the inexpensive neon tester, consisting of a neon glow lamp in series with a current-limiting resistor, housed in a neat plastic enclosure terminated with flexible test leads. This forms a convenient and reliable means of testing for the presence of ac or dc voltages.

In electronics, the "state of the art" has progressed rapidly, finding new applications for the glow lamp as a circuit element. Much of this progress results from the increasing use of solid-state devices, many of them, like the transistor, requiring comparatively low currents and voltages for operation.

Some of the characteristics that make the miniature neon lamp particularly appealing to the hobbyist-experimenter are its low cost, long life, dependability, and the ease with which it can be made to work in extremely simple circuits. At the same time, but probably unknown to the majority of persons who work with electronics, the neon lamp can be used in some circuits and applications that are quite sophisticated, complex, or exacting.

This book is offered to present the student, hobbyist, technician, and engineer with a more complete account of the properties of neon lamps and to acquaint them with some of the many ways in which neon lamps can be utilized.

WILLIAM G. MILLER

1

The Neon Lamp

The neon lamp is basically a glass envelope filled with gas and containing two or more electrodes. It is also referred to as a gas tube, gas diode, glow tube, and glow lamp.

It might be interesting to note that the neon lamp does not always contain neon alone, but may contain a mixture of gases. Some gas lamps have no neon at all, but are included in this discussion because the design considerations for all types are similar. Long term reliability, low cost, and small power and space requirements help account for its increased popularity.

BASIC OPERATION

The miniature neon lamp is a cold-cathode device and requires no heater. The electrodes are separated by an average distance of ⅛ inch inside the gas-filled envelope.

Under initial conditions, the gas acts as an insulator with a resistance of about 1000 megohms. If a variable voltage is applied across the electrodes (Fig. 1) and increased to approximately 50 volts, there will be essentially no current flow, due to the high insulation resistance of the gas.

Actually the gas atoms are constantly being bombarded and ionized by external forces such as light. The positive ions thus generated are attracted to the cathode, which has a negative charge. The electrons that are liberated in the generation of positive ions are accelerated to the positive anode, striking

other atoms as they travel, but they rarely attain enough velocity to dislodge more electrons and create new ions.

This velocity can be attained if an external voltage of sufficient amplitude is applied. When an electron dislodges additional electrons, which in turn create even more ions, the process is referred to as "run-away" or "avalanche," and constitutes current flow. Run-away can be self destructive if uncontrolled, so a series current-limiting resistor (R_s), must be included. The exact value of voltage needed to start the ionizing action is called the breakdown voltage.

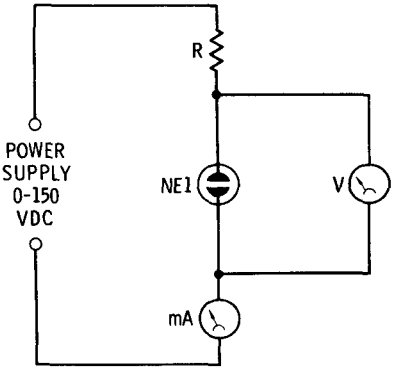


Fig. 1-1. Voltage and current in a neon-lamp circuit.

When breakdown voltage is applied to the circuit in Fig. 1-1 there will be a sharp deflection of the ammeter, and the voltmeter reading will drop to a value known as the maintaining voltage of the lamp. The maintaining voltage of a lamp remains relatively constant over a wide current range.

The actual values of breakdown and maintaining voltage will vary from one gas tube to another. They depend on many factors, such as physical design, external radiation, and circuit design.

The curve in Fig. 1-2 illustrates the characteristics of a typical gas discharge device (glow lamp). It can be seen that dynamic current does not begin to flow until the voltage reaches point A. Breakdown occurs at point B, or 110 volts, and the maintaining voltage is approximately 85 volts (point D). When breakdown occurs, the current flow is said to be self-sustaining. This means that the applied voltage can be lowered to some value above the maintaining voltage and current flow will still continue to increase until the normal glow

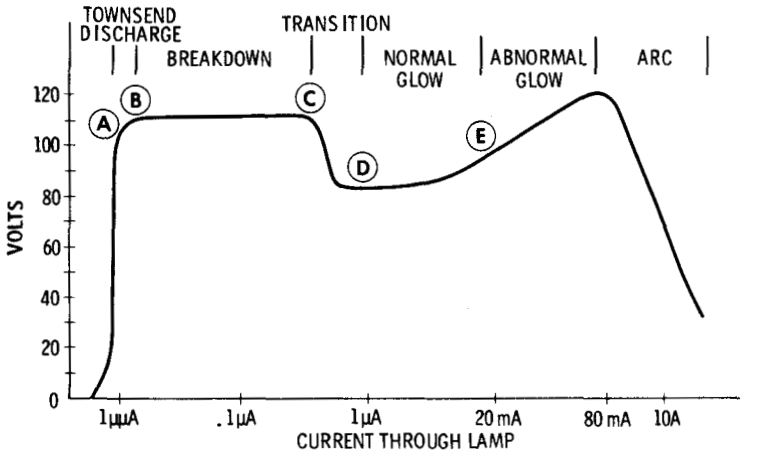


Fig. 1-2. Characteristic curve of a neon lamp.

region is reached. Note that the current scale is not linear, but compressed for convenience.

COROTRONS

Corotron is the name given by the manufacturer to a line of gas-filled diodes that are used to regulate voltages between 350 and 30,000 volts. Unlike the conventional regulator, they do not glow, but operate on the slightly positive slope prior to breakdown.

This is called the "corona mode" of operation and closely resembles the action of a zener diode.

Corotrons are free of voltage jumps, oscillations, and photosensitivity. Current capability is, however, quite small. The maximum figure for T2 types is 100 μA and 3 mA is the limit for even the largest type. Care must be taken never to exceed the peak current rating or breakdown will occur and permanent component damage may result.

PROGRESSIVE EXPLANATION OF TERMS

Ion—An atom with an excess or deficiency of electrons.

Ionization—In glow lamps, the process of separating an electron from an atom, creating a positive charge and a free electron.

This may be caused by collisions between atomic particles, the application of a voltage, an electrostatic field, X rays, ultraviolet rays, cosmic rays, and radioactivity.

Corona—The visible glow of an ionized gas surrounding the cathode.

Breakdown Voltage—Also called ionization voltage, striking voltage, and firing potential. It is the voltage needed to make a lamp glow. This is determined mainly by the type of gas, electrode spacing, pressure, and external ionizing forces, such as light.

Static Breakdown Voltage—The breakdown voltage under controlled conditions, which include: freedom from electrostatic fields, 5 to 50 foot candles of ambient light, and a 24-hour period in a non-conducting state.

Townsend Discharge—An avalanche type of electron flow that occurs just before breakdown voltage is reached. It is not a self-sustained current flow.

Maintaining Voltage—Also called holding voltage. It is the voltage across the lamp after breakdown. This voltage is at its minimum in the normal glow region (Fig. 1-2, point D to E).

Normal Glow—The mode of operation that allows maximum current variation with minimum change in voltage.

Abnormal Glow—A region of operation that is arrived at by increasing the lamp current beyond the normal glow region (Point E, Fig. 1-2).

Extinguishing Voltage—The voltage at which a lamp will cease to glow.

Differential Voltage—The difference between the breakdown voltage and maintaining voltage.

Ionization Time—The time required for a lamp to enter normal glow after application of a voltage that is in excess of the breakdown voltage.

This time may be well under 50 μsec if the applied voltage is 30 percent greater than the breakdown voltage.

Deionization Time—Definition 1: The time it take a lamp to return to its static breakdown voltage after current ceases to flow.

Definition 2: In a dc circuit, if a lamp is extinguished by a rectangular pulse, it is the time which must elapse before 90 percent of the original breakdown voltage can be reapplied and still not cause breakdown.

The first definition is used for most circuit applications, but if higher frequency oscillators and counters are being considered, the latter definition would be more useful.

Deionization time is affected by tube construction, the magnitude of the conduction current, and most of all by the amplitude of the extinguishing voltage.

Dark Effect—The effect that light has on breakdown voltage. Higher ambient light levels produce lower breakdown voltages. If a lamp is to be operated in total darkness, it is usually necessary to simulate ambient light by the addition of a small amount of radioactivity.

Standing Rise—The rise in breakdown voltage that some lamps incur after extended periods of storage. This is mainly caused by the glass and other internal solids releasing gas molecules.

Negative Resistance—An increase in current caused by a decrease in voltage. This can be noted on the characteristic curve of most lamps. In Fig. 1-2 this corresponds to that part of the curve between points C and D.

Design Current—The value of operating current upon which the end-of-life figures are based.

Transmission Time—The time required for an input level change to appear on the output of a lamp already in the conducting state. This is usually less than 8 μsec and is a function of the conducting current.

End-of-Life—A glow lamp that is used for its light output is said to have reached its end-of-life when the light output falls to 50 percent of its original value. If a lamp is used as a circuit component, the end-of-life occurs when the characteristics fall out of specifications. Lamps operated on ac have longer life figures due to shorter duty cycle.

Aging—The process of operating a new lamp at an increased current level for periods in excess of 24 hours in order to stabilize its characteristics.

The aging process varies for different lamps and is usually done in the factory. However, aging is not required for all lamp applications.

Sputtering—A phenomena that occurs when lamps are operated at higher currents. Certain quantities of the metal cathode material will vaporize, and when the vapor comes in contact with the cooler glass envelope, it solidifies. This thin film

of sputtered metal is opaque and restricts light output, but it also increases electrical stability.

Polarization—A lamp is said to be polarized when its characteristics change with a reversal of polarity. Lamps that are aged or operated on dc exhibit this effect. Lamps that are aged on dc are coded to designate the anode or positive terminal.

Work Function—A measure of the ability of a material to give up electrons. Molybdenum is said to have a lower work function than nickel because it releases more electrons for a given voltage.

PHYSICAL CONSIDERATIONS

Gases

Gases—The inert or "rare" gases are used in the manufacture of glow lamps. Neon is the basic gas, but other gases may be used in mixtures to achieve special results.

Neon—The basic glow-lamp gas, noted for its high light output, and low breakdown and maintaining voltage. The characteristic color of the neon glow is red-orange.

Helium—A low breakdown, low light-output gas that may be mixed with neon to produce a specific value of breakdown or maintaining voltage.

Argon—This gas has a higher breakdown voltage, but if as little as 0.1 percent is added to neon, the breakdown voltage for the mixture is lower than for either gas alone. Pure argon is used as an ultraviolet light source.

Xenon—A high-breakdown gas that is used to produce a brilliant white light and is also used as a noise source. This gas has not found much application in miniature gas tubes.

Krypton—A gas with qualities similar to argon. It is added to neon to raise the breakdown and maintaining voltages, and is an excellent source of ultraviolet light.

Krypton 85—A radioactive isotope of krypton that is added to neon or other gases to provide partial ionization and stability to compensate for the dark effect.

Electrodes

Material—Nickel and molybdenum are the two common electrode metals. Molybdenum tends to lower the breakdown and maintaining voltage and can carry higher currents.

Spacing—Increased spacing between the electrodes increases breakdown voltage but has little effect on the maintaining voltage.

Coating—Emissive materials such as barium and strontium are used to coat the electrodes and allow the cathode to give up electrons more freely. This results in lower breakdown voltages and higher, more uniform light output. Gas tubes that use emissive material will change their characteristics with time. NE2 lamps are in this class.

Size—The size of an electrode will determine its light radiating area and current carrying ability.

Pressure

Increasing the internal gas pressure will raise the breakdown voltage of the lamp without major changes in the maintaining voltage. Lamps with a high differential between breakdown and maintaining voltage are useful as counters, high power oscillators, and energy transfer diodes.

In general, high-pressure gas tubes will exhibit poor light output and an unstable corona that results in voltage jumps and noise.

Temperature

Gas tubes have a negative temperature coefficient. Most indicator types will drop 50 mV in maintaining voltage for each Celsius (centigrade) degree of increase. Circuit component types and regulators may have a figure as low as −2 mV per degree C.

Radiation

The electrical characteristics, the electrodes, and the gas are relatively unaffected by gamma radiation. The glass, however, will darken and become brittle.

Rf radiation or a strong ac field will ionize the gas directly.

2

Indicators

The miniature glow lamp has found widespread use as an indicator in electronic, commercial, and industrial equipment. A brief comparison to the incandescent type is offered to help explain both their popularity and their limitations.

INCANDESCENT VERSUS NEON

A specific lamp must be indicated if the ratings are going to be based on such items as temperature, vibration, shock, or humidity. Both types have indicators that perform well in these areas.

The tungsten filament is basically a low-voltage, high-current device, while the neon requires higher voltages and smaller currents. The efficiency figures of each vary widely, but in comparing the NE2H with CM8-806, which is a Chicago Miniature, 100,000 hour, tungsten-filament lamp, the efficiencies were found to be equal at 2.2 lumens per watt. If life expectancy is plotted against cost, the neon lamp is unparalleled. Even the most economical glow lamps have a life of 20,000 hours.

As a result of efforts to improve the tungsten life figures, several lines of miniature incandescents have appeared on the market with life expectancies of 20, 50, and 100 thousand hours. These lamps are relatively expensive and the life figures are based on "burnout." Since neons do not burn out,

their life is calculated on other factors, such as tube darkening. (Envelope darkening can occur with both types.)

When a high-brightness neon is operated at half its design current, it will give over a million hours of use before darkening restricts its light output by 50 percent.

Neon lamps perform poorly at altitudes higher than 70,000 feet, where the lower atmospheric pressures encourage external corona and arcing.

The tungsten-filament lamp can produce high light intensities over a wide range of light frequencies. Filters of paint, plastic, etc., can be used to "color" the incandescent light, but this cannot be done to any usable degree with neon. Colors such as green, seen in outdoor neon signs, are the result of phosphors or a combination of helium and mercury vapor used with noviol or uranium glass. Helium and mercury vapor are usually considered unsuitable for use in miniature lamps.

As a result of the preceding comparison, it would be reasonable to assume that cost and life expectancy are the main reasons for selecting a neon as an indicator. Actually, all but a very few glow lamps can be called indicators because they emit light. There are, however, three basic types that are designed specifically for their light radiating ability.

STANDARD BRIGHTNESS

The NE2 is in this category and is the most popular of all the lamps. It has the lowest current requirements and exhibits a gradual change in characteristics with extended operation. The light output falls off at a uniform rate, due to sputtering, and the breakdown voltage rises slightly.

If you double the design current, you will double the light output, but its life expectancy should be divided by 8. The inverse holds true if design current is halved. Light output will be halved, but life figures can be multiplied by 8.

HIGH BRIGHTNESS

The NE2H is a lamp of this type and differs from the standard-brightness variety in several ways. It has a higher initial breakdown voltage, and when it reaches its end of life, the

breakdown rises to a point that is higher than the peak line voltage (160V), and the lamp will no longer ignite.

The high-brightness lamp has 10 times the light output of a standard brightness unit and can carry more current. It maintains a fairly steady characteristic until it reaches its end of life. The maintaining voltage of this type of lamp is unstable. "Voltage jumps" and high noise levels are not uncommon, so this restricts its use as a circuit element.

As in the case of the standard-brightness lamp, if the design current is doubled or halved, the light output will also be doubled or halved, but the life figures will have to be multiplied or divided by 64 instead of 8.

ULTRAVIOLET

Gas tubes filled with argon fall into this category. They emit a deep blue light, and are used primarily for their color. Very little true ultraviolet radiation is able to penetrate the glass envelope so they are relatively safe to work with. The AR9 is an example of this type.

CONSTRUCTION

American and foreign companies have made efforts in recent years to change the physical design of the lamps, either for esthetic and space requirements or to increase the light output.

General Electric has a complete line of lamps that have formed tips instead of the standard drawn tip. These lamps not only look better but increase the light output when viewed end-on.

Tech-Neon, Signalite and GE all offer acid-frost lamps, which give a pleasing, uniform light output.

The British, French, Belgian, and Italian companies offer some lamps that are exotic by American standards. Most of these companies manufacture a line of lamps with a lens that is an integral part of the envelope. They also produce lamps with axial leads. One European manufacturer even produces a lamp that glows green. This is done by coating the inside with green phosphor and filling the envelope with argon. All of these lamps are expensive, and for that reason the Ameri-

can companies hesitate to produce them. There is also a major glow-lamp manufacturer in Canada that offers essentially the same products as the American companies.

The recent trend by many equipment manufacturers has been to use lamps that have been encapsulated in plastic along with the ballast or series resistor. This improves the appearance and greatly simplifies mounting. Many domestic and foreign companies, including Japanese, offer this type of indicator.

PRACTICAL INDICATORS

Some lamps come with a series or current-limiting resistor attached, but, if not, its value may be calculated. The glow lamp specification sheet will recommend a particular value for standard line voltages, but the designer may have a wide range of voltages to contend with.

Example: It is necessary to have a visual indication that power has been supplied to the circuit in Fig. 2-1. For illustra-

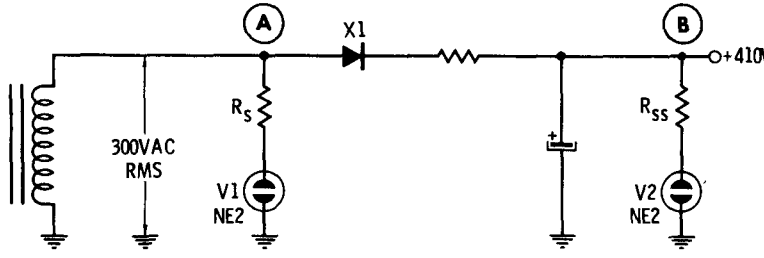


Fig. 2-1. Neon indicators in a power supply.

tion, we chose point A and B as possible locations. The formula for both resistors is the same, but they are handled differently. The formula is:

$$R_s = \frac{E_{app} - E_{maint}}{I_{design}}$$

In other words the resistor has to drop the difference between the applied voltage and the maintaining voltage of the lamp at the design current.

Solution for I1:

$$R_s = \frac{300 - 39}{.0005}$$

$$R_s = 510k$$

Solution for I2:

$$R_{ss} = \frac{410 - 55}{.0005}$$

$$R_{ss} = 680k$$

Resistors are to the closest 10% EIA value.

Since I1 is in an ac circuit, rms values were used. Location B will provide a positive indication of B+ but only one electrode will glow. The total measured light output from both lamps is approximately equal.

The indicator in Fig. 2-2 will ionize only when E_{app} or supply voltage has reached 150 Vdc. The value of R_s is solved in the usual manner and forms part of a voltage divider with R_d. R_d was selected to provide the maximum rated breakdown voltage (90) at point A, when the supply reaches 150 volts. Greater accuracy can be had if the exact value of breakdown is known. I1 in Fig. 2-3 will give a visible indication of voltages throughout the range shown. The circuit functions in the usual manner down to about 500V at which point C, I1, and R_s will switch to relaxation oscillations and the lamp will flash brightly.

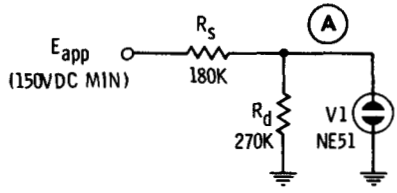


Fig. 2-2. Voltage level indicator.

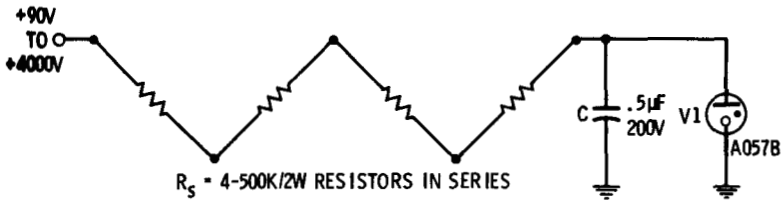


Fig. 2-3. Wide-range indicator.

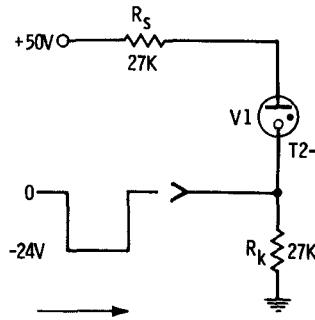


Fig. 2-4. Nonlatching indicator.

The simple nonlatching circuit in Fig. 2-4 is useful when operation is required from a low voltage source (24V), such as a transistor collector. The value of the supply voltage is less than the lamp's lowest rated extinguishing voltage. A negative 24-volt pulse is added algebraically to the supply voltage to total 74 volts, which equals the highest rated breakdown voltage for the lamp. The lamp can remain on only when the negative pulse is present on the cathode.

Fig. 2-5 shows another nonlatching circuit that features use of low voltage transistors (18V) and even lower control voltages (+1V). Q1 is normally saturated so the 62V developed by the zener diode is not enough to ionize the 5AGA. When Q1 is cut off by a +1V pulse or by grounding the base, the −18V

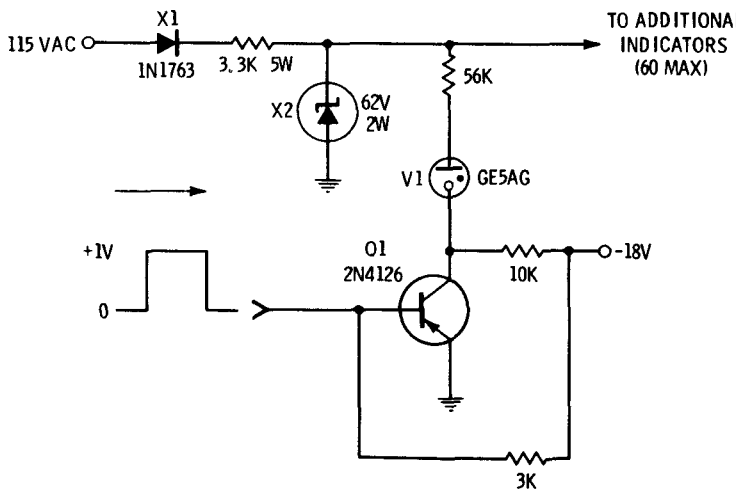
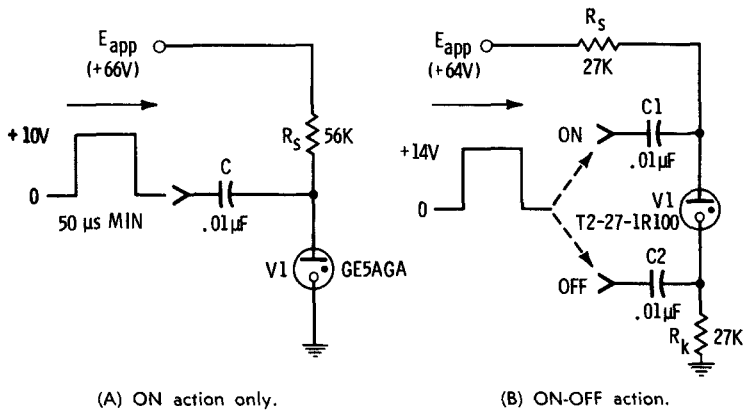


Fig. 2-5. Nonlatching indicators using low-voltage transistors.

will be felt at the cathode of the lamp through the 10k resistor. This voltage which is added to the zener voltage should exceed the lamp's maximum rated firing voltage. The lamp is extinguished 60 times a second by the ac input so there is no need for a separate turn-off circuit.

The power supply voltages in Fig. 2-6 are selected to be lower than the minimum rated breakdown voltage and higher than the maximum rated maintaining voltage. The input pulse is added to E_{app} to cause breakdown and the supply will support ionization at the maintaining voltage. Fig. 2-6B illustrates how the same principle may be used to extinguish the lamp.



(A) ON action only. (B) ON-OFF action.

Fig. 2-6. Latching indicators, low-voltage drive.

Availability of high-quality, low-leakage transistors at prices considerably less than a dollar has made direct operation of neon lamps economically practical.

The transistor selected for the type of circuit shown in Fig. 2-7 must be able to withstand voltages that are equal to E_{app} minus the lowest rated maintaining voltage of the neon lamp. The 1.2K resistor prevents false starting by minimizing leakage effects.

In computer technology and other related fields, it is sometimes necessary to have a visual indication of a very short pulse. Since pulses shorter than 50 μs rarely can cause ionization, special circuits are required. The circuit in Fig. 2-8 will respond to pulses shorter than 1 μs and cause the neon lamp to glow. The incoming pulse charges C through the dynamic

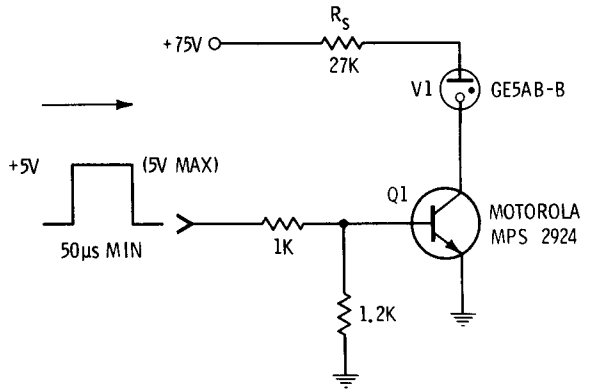


Fig. 2-7. Direct transistor operation.

impedance (50Ω) of the 1N38. This switches the 2N337 on and fires the neon lamp. Since C cannot discharge through the diode, the transistor will remain on until C discharges through R_k and Q1. Increasing the value of C will allow the lamp to remain on longer but will decrease the input sensitivity.

Five different conditions may be represented by a single lamp as shown in Fig. 2-9. In position 4, R_o is too large to support ionization so RC oscillations will result from the charging and discharging of the .01 μF capacitor. Fig. 2-10A shows a circuit that will indicate a blown line fuse and Fig. 2-10B will indicate a good fuse.

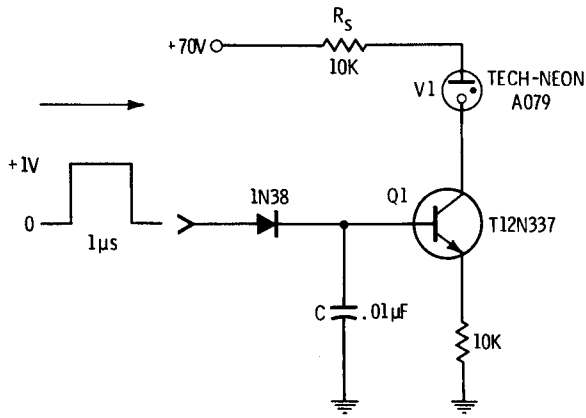


Fig. 2-8. Short-pulse indicator.

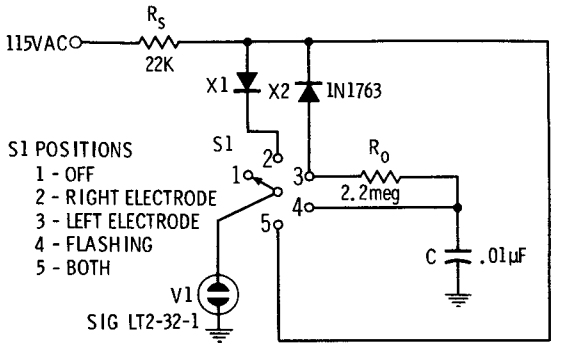


Fig. 2-9. Five-state indicator.

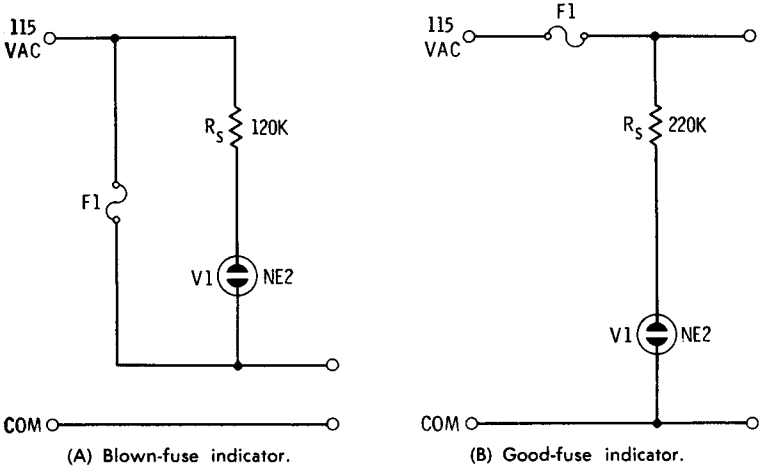


Fig. 2-10. Fuse indicators.

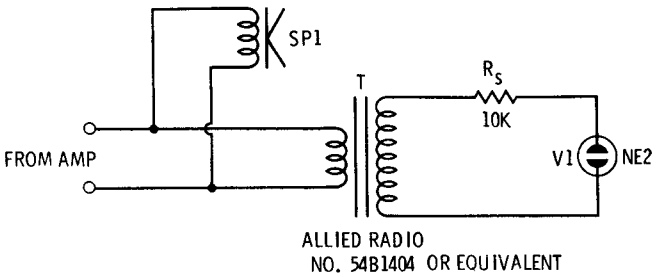


Fig. 2-11. Speaker operation indicator.

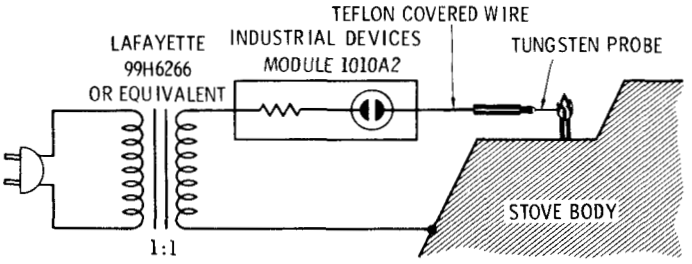


Fig. 2-12. Pilot flame monitor.

In remote or multiple speaker installations, it is sometimes desirable to have a visible indication of operation. A small audio output transformer, with the low impedance side connected to the speaker terminals as in Fig. 2-11, will step up the small audio voltage to a value that will operate the neon lamp. The transformer is not critical, but the brightness of the lamp will be affected by the Z or turns ratio, as well as the amplifier output.

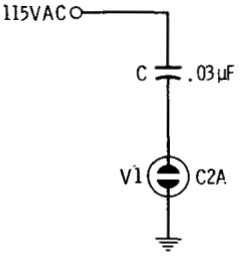


Fig. 2-13. High-efficiency one-million hour circuit.

The novel circuit in Fig. 2-12 utilizes the flame as a high Z conductor to keep the neon lamp lit. When the pilot light goes out, the random concentrations of cold gas will act as an open circuit.

When extremely long life and low power dissipation are required, the circuit in Fig. 2-13 might be considered. Instead of resistance, X_c is used to limit the current to the desired value. In this example the C2A (NE2H) is operated at half its design current, so its life figures are increased by a factor of 64.

3

Voltage Regulators and References

DESCRIPTION

Recent technology and manufacturing techniques have produced a miniature voltage regulator that has the physical dimensions of other neon lamps, but is capable of current variation over ranges as wide as 15 mA. Its maintaining voltage will change less than one volt, and life figures are in excess of 20,000 hours. These gas diodes can replace the older 7- and 8-pin "tube" type regulators in all but a few applications. They are ideally suited for printed circuit boards, encapsulation, and other modern fabrication methods.

APPLICATION

In many cases, the same gas tube may be used both as a regulator and as a reference. The GE 5AB lamp, for instance, is used extensively as a voltage reference, but also provides excellent regulation of vacuum-tube screen-grid voltages. This lamp is simply an aged NE2 with a small amount of radioactivity added for the reduction of the "dark effect." The electrodes have an oxide coating and accordingly the lamp's characteristics will change slightly with use. This effect can be disregarded in many applications such as the reference

voltage in series-regulated vacuum-tube power supplies, where gradual change over a period of months can be tolerated.

On the other hand, applications such as voltage calibrators and unmanned communication sites may require not only good regulation, but a specific voltage value over extended periods of time.

REGULATOR CONSTRUCTION

The high-current regulators achieve their characteristics by several means. The electrodes are made longer and larger in diameter to increase the current carrying ability. European manufacturers use an anode that is somewhat smaller than the cathode. American firms favor identical electrodes and there appears to be some controversy as to which one produces the best results.

Both designs utilize electrodes that can carry current loads in excess of 60 mA. The limiting factors are the bulb temperature and the point at which the tube will arc.

The electrodes of a high-current regulator are pure metal and contain no oxide coatings. This is a necessary condition for a wide current range and long-term stability. They also are aged at higher currents for longer periods than the reference type diode.

Extended aging is needed to sputter or vaporize the cathode surface metal that may have trapped gas atoms during manufacture. This process, sometimes referred to as "cleaning up," is essential for reliable operation. These gas tubes can be recognized by their characteristic black or silver appearance, which is caused by the deposit of sputtered cathode material on the wall of the lamp.

CIRCUIT DESIGN CONSIDERATIONS

Since it is not the purpose of this book to present an exacting mathematical analysis of neon-lamp circuits, certain assumptions have been made that are not necessarily so.

The formulas, for instance, have omitted resistor tolerances, temperature coefficients, and the dynamic impedance of the conducting gas tube. All formulas have been reduced to the simplest possible form and, in some cases, expressed literally

rather than mathematically. Selection of resistors was done by choosing the standard EIA value that was closest to the calculated value.

PRACTICAL REGULATOR AND REFERENCE CIRCUITS

The circuit in Fig. 3-1 is the basic and most widely used method of obtaining a reference voltage. The supply voltage (E_{app}), must exceed the rated breakdown voltage and is applied to V1 through the current-limiting resistor R_s. This causes the lamp to ionize and its characteristic maintaining voltage (E_{maint}) will appear at point A. Once the correct tube has been selected, only the value of series resistance must be calculated.

$$R_s = \frac{E_{app} - E_{maint}}{I_{design}}$$

The maintaining voltage and the design current can readily be obtained from the specifications sheet.

The foregoing formula will hold true as long as R_x remains relatively high. It can be seen that R_x forms a voltage divider with R_s, and under initial conditions breakdown or "firing" voltage must appear at point A or V1 will not ionize. Once the gas tube conducts, the value of R_x must remain high enough to sustain ionization. Voltage-divider action is still present at point A and if this voltage drops below the maintaining voltage the lamp will be extinguished. In other words, if the circuit in Fig. 3-1 is used, the load current cannot exceed the design current.

Fig. 3-2 illustrates a circuit that compensates for unusually wide variations of input voltage. V1 is rated to regulate over a 15 mA range. R_s was chosen to cause 1 mA to flow at +140 V. The minimum load resistance is calculated by determining

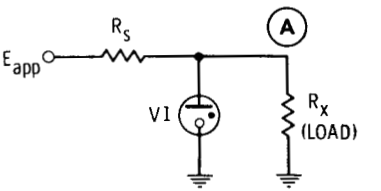


Fig. 3-1. Basic voltage-reference circuit.

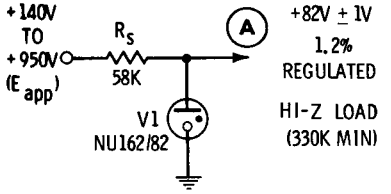


Fig. 3-2. Voltage regulator for input variations.

what value R, in series with R_s, is necessary to cause the maximum rated E_{bkdwn} (118V) to appear at point A when the minimum voltage (+140V) is applied.

It can be seen in Fig. 3-3 that the same gas tube can be used to compensate for changing load conditions. If the NU 162/82 regulator is operated at its maximum rated current, a regulated 0-5.5 mA output is realized. Actually this circuit would be capable of a regulated 15 mA output, except that under initial conditions the value of R_x would be so low as to prevent breakdown voltage from appearing at point A.

The simple circuit in Fig. 3-4 compensates for both input and output voltage variations. It represents a compromise of the circuits shown in Figs. 3-2 and 3-3.

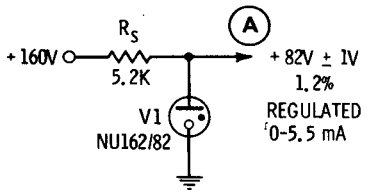


Fig. 3-3. Voltage regulator for load variations.

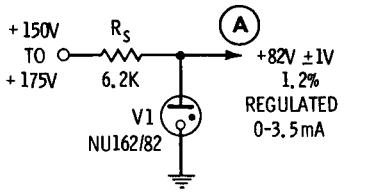


Fig. 3-4. General-purpose voltage regulator.

The voltage divider limitations of Figs. 3-2, 3-3, and 3-4 are overcome by the addition of a replacement-grade silicon diode X1, and a "firing" resistor (R_f), as shown in Fig. 3-5.

Under initial conditions, the load may draw 15 mA and the voltage at point A will never reach breakdown. This "low" voltage is isolated from the gas tube by diode X1, so that V1 may be ionized by the current through R_f. After ionization point A will be positive with respect to point B, so X1 will conduct and operation will be the same as in previous circuits. The value of R_f is calculated in the same manner as R_s except that the value of I is small. Current through R_f must be large

enough to sustain ionization, but can be considerably smaller than the .5 mA arbitrarily chosen in Fig. 3-5.

A stable higher voltage reference is achieved in Fig. 3-6 by operating two gas tubes in series. The reference voltage is the sum of the two maintaining voltages and E_{app} must exceed the sum of the two breakdown voltages.

Fig. 3-7 illustrates a useful circuit that produces a high reference voltage with relatively small supply voltage. In this instance, the series breakdown voltages exceed E_{app}. E_{app} may drop as low as +130V and still deliver a precise 124-volt reference. This is done by diode isolation and shunt starting as in Fig. 3-5. R_f fires V2 and R_{ff} fires V1. R_s is calculated as in previous circuits.

The 300-volt regulator shown in Fig. 3-8 can be contained in a space the size of a 20-watt resistor and can deliver 3.6 watts of power to the load. Since the total breakdown of the three gas tubes in series equals 450 volts, R_f and R_{ff} must be used to initiate ionization. R_f fires V3 and R_{ff} fires V1. V2 will then ionize because of the potential difference between points B and C.

Parallel starting can be used for any number of tubes. Fig. 3-9 shows two methods for an identical 4-tube supply. In Fig. 3-9A, the use of a single resistor, R_f, enables the minimum applied voltage to be reduced from 600V to 500V. Two additional resistors, R_f and R_{ff} in Fig. 3-9B, further reduce the voltage requirements to 450V. Fig. 3-9B is usually the preferred method, as the starting resistors are ¼-watt 20-percent components, and the main savings are realized in applied power and the power dissipated by R_s.

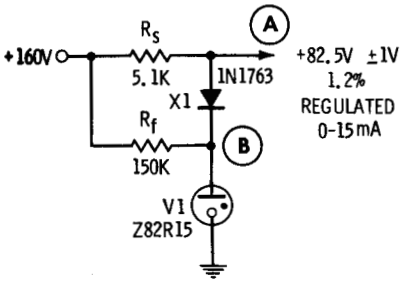


Fig. 3-5. Shunt starting regulator with diode isolation.

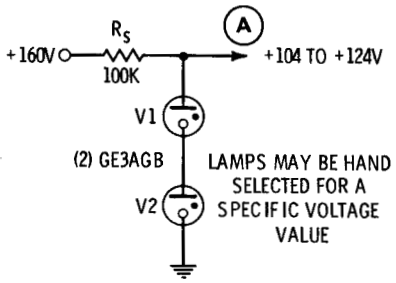


Fig. 3-6. Series starting, series operation voltage reference.

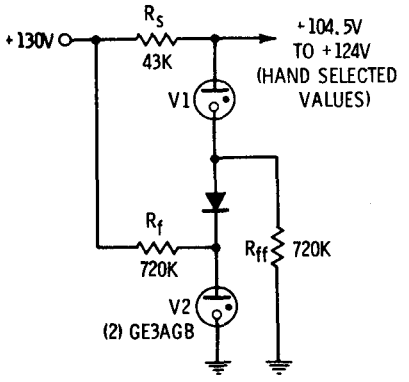


Fig. 3-7. Shunt starting, series operation voltage reference.

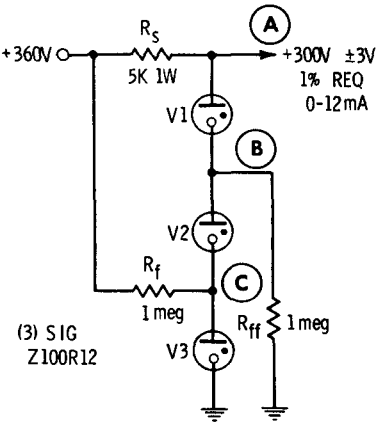
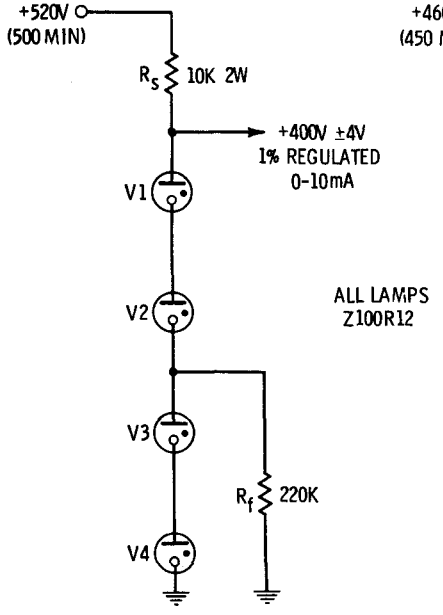
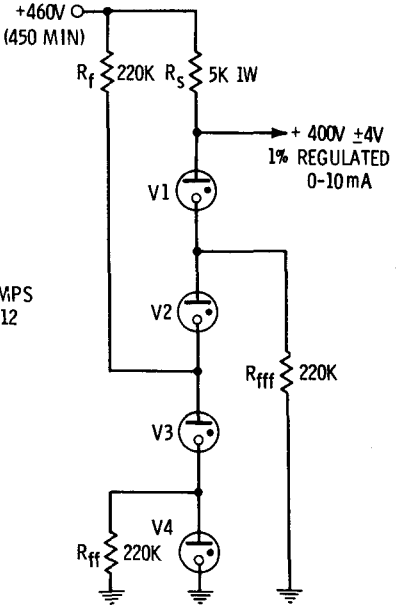


Fig. 3-8. Shunt starting, series operation high-voltage regulator.

Small capacitors may also be used in place of the firing resistors. "Capacitive starting" is usually more expensive and requires more space, but these circuits dissipate less heat and require less current.



(A) Using one shunt resistor.



(B) Using three shunt resistors.

Fig. 3-9. Shunt starting, series operation four-tube regulators.

A cascaded reference is used when an extreme degree of regulation is required. In Fig. 3-10 a change of 100V at the source will produce a change of less than 1 part in 10,000 at the output. The maintaining voltage (E_{maint}) of V1 must exceed the E_{bkdwn} of V2. R_s and R_{ss} are found by the formulas:

$$R_s = \frac{E_{app}(min) - E_{maint}(V1)}{I(V1min) + I(V2)}$$

$$R_{ss} = \frac{E_{maint}(V1) - E_{maint}(V2)}{I(V2)}$$

V1 may be a more economical lamp and still provide a reliable circuit.

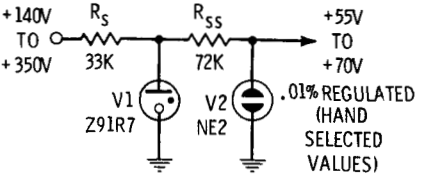


Fig. 3-10. High-stability cascaded reference.

The maintaining voltages of V1 and V2 in Fig. 3-11 are close enough to make parallel operation practical. Diodes X1 and X2 isolate the load from R_f and R_{ff} for initial ionization and also serve to isolate V1 from V2. The value of R_s is found by treating V1 and 2 as one gas diode with twice the current rating. X1 and X2 are replacement-grade silicon diodes.

The novel circuit shown in Fig. 3-12 may be used to establish precise low-voltage references. The output voltage is the

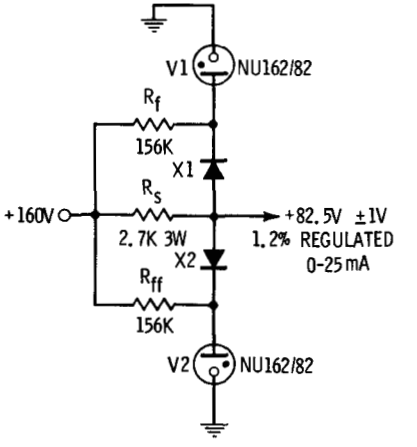


Fig. 3-11. High-current parallel regulator.

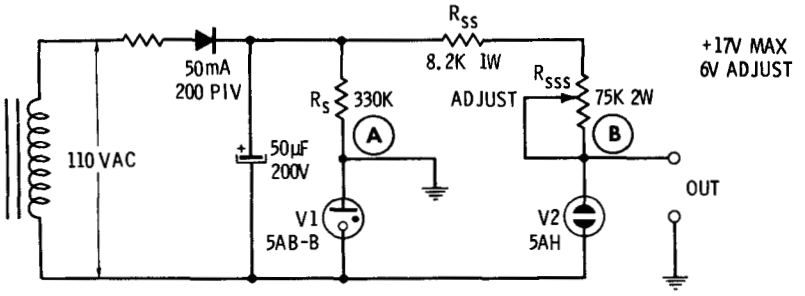


Fig. 3-12. Differential low-voltage reference.

difference between the maintaining voltages at points A and B.

The high-current regulator in Fig. 3-13 appears to be a conventional shunt starting circuit, but a closer look at the values and performance figures will indicate a different mode of operation.

Most circuit designers will agree that the load current should rarely exceed the rated tube current and this premise is true if you do not place any limitation on the minimum amount of current that may be drawn by the load. If the "zener diode" approach is used, the load current may be many times the tube's maximum rated value.

This is possible if we consider that when a gas diode regulator is rated at 12 mA, that means it will stay within specification over this range. It does not mean that 12 mA will be delivered to the load. Tube V1 is still regulating 100V ± 1V over a 12-mA range, but at a 110-mA level. If the supply voltage is held at a constant 160V, the load may vary between 100 to 120 mA and still be within 2 percent of 100V. The im-

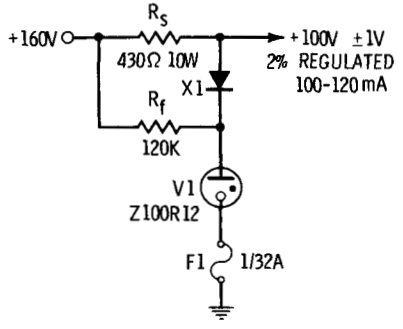


Fig. 3-13. High-current, high-voltage regulator.

portant limitation of this circuit is that there is a minimum current the load must draw. Fuse F1 is included to protect V1, if the load is reduced or removed.

Design procedure for Fig. 3-13:

1. Select regulator tube after determining the maintaining voltage required and range of regulation.
2. Let R_f be 120K unless the supply voltage is over 200 volts, then double or triple this value. (Not critical.)
3. Let X1 be any 400-PIV, 200-mA diode or better.
4. Find $I_t = I_x + I$ (V1)

Find $R_t = \frac{E_{app}}{I_t}$

Find $R_x = \frac{E_{maint}}{I_x}$

Solution:

$$R_s = R_t - R_x$$

where,

E_{app} is the supply voltage,
I_x is the minimum current required by load,
I(V1) is the maximum rated lamp current,
R_x is the load resistance,
R_t is the total circuit resistance,
I_t is the total circuit current,
R_s is the series limiting resistor,
E_{maint} is the maintaining voltage.

Fig. 3-14 is one variation of a popular circuit. The wide variety of screen-grid voltages and currents makes a standard circuit impractical. The voltage needed at point A is usually high enough to require two or more lamps in series. R_s, V1, and V2 comprise the regulator system, but any of the systems previously discussed may be used. I_{design} is the maximum screen-grid current.

Algebraic addition can provide a regulated low-voltage, wide-temperature-range supply as shown in Fig. 3-15. The negative 100 volts developed by V1 is added to the positive 82 volts of V2 at point A and the result is a negative 18 volts. V1 is rated at 10 mA but R_s had to be increased to 18K in order to sustain ionization of V2. C1 is an example of capacitive starting and is included to ensure that point A will reach

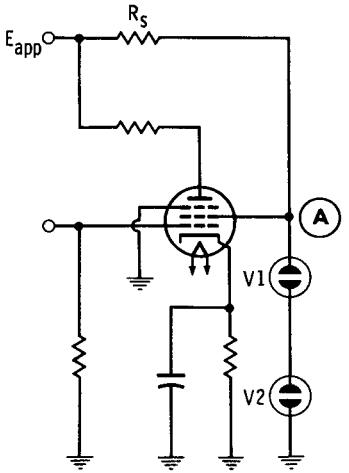


Fig. 3-14. Vacuum-tube screen-grid regulator.

the breakdown voltage of V2. The filter capacitors may be lower in value and if 220 Vac is used, C1 may be omitted, R_s and R_{ss} may be calculated for full tube current, and regulation will occur over a 10 mA range.

The circuit in Fig. 3-15 has one advantage over other low-voltage types in that it has a common ground. In all differential or algebraic circuits, the tolerances will add, so the final performance figures will be half that for a single tube.

V1 in Fig. 3-16 is a voltage reference for V2. In this series-pass voltage regulator, current carrying ability and regulation are the prime considerations—an AO57B would be a suitable

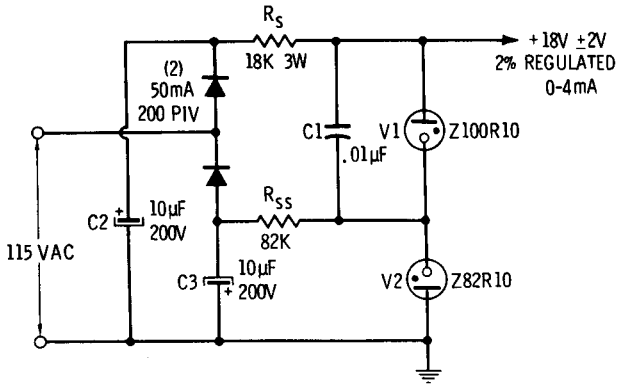


Fig. 3-15. Algebraic low-voltage regulator.

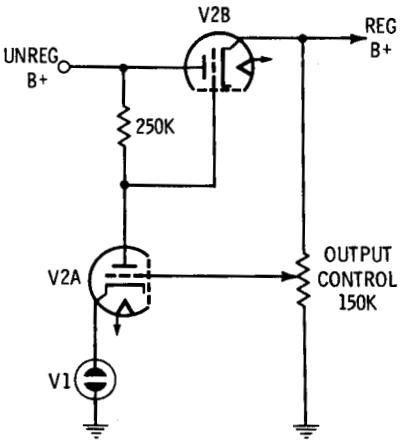


Fig. 3-16. Series-pass regulated reference.

choice. The maintaining voltage of V1 will determine the low-voltage limits of the regulator. V2 can be any miniature dual-triode that meets voltage and current requirements.

High voltage and high current are both available from the circuit illustrated in Fig. 3-17. This circuit can be constructed for less than $2.00 at present list prices and is physically small. If better regulation for input variations is required, the T2-32-1 lamps should be pre-aged at 10 mA for 24 hours. The sum of the two maintaining voltages minus the junction drop (0.6V) will determine the exact output voltage.

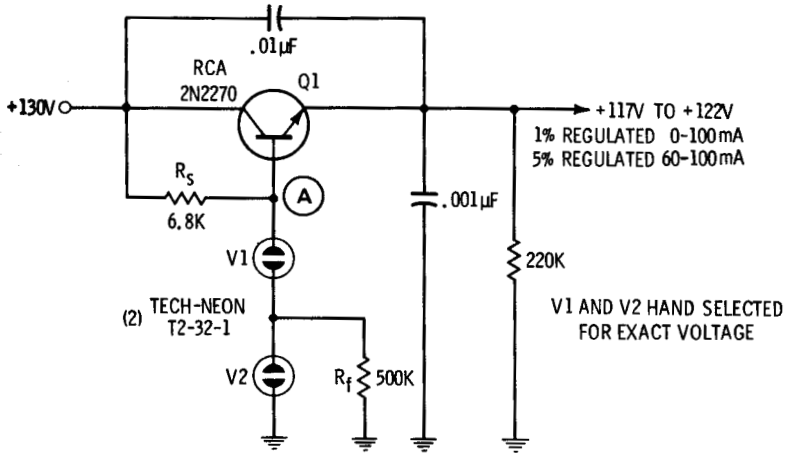


Fig. 3-17. Transistorized series voltage regulator.

$$R_s = \frac{E_{app} - E_{maint}\ \text{(both tubes)}}{2\left(\frac{I_{load}}{\beta\ \text{(transistor beta)}}\right)}$$

R_f is the shunt-starting resistor and the value is not critical. Shunt starting in this case is highly desirable as it reduces the value of E_{app} that is needed. The closer the voltage at point A is to E_{app}, the less power Q1 will have to dissipate. It also allows lower transistor voltage ratings. The capacitors are for junction protection and are not critical.

4

Oscillators, Pulse Generators, and Flashers

Simple gas-tube relaxation oscillators are capable of producing a wide variety of complex waveforms. Their main limitation is the useful upper frequency limit. Pulses with rise times of less than 1 μs are not unusual, but repetition rates or operating frequencies of more than 10 kHz are difficult to achieve.

SINGLE-LAMP OSCILLATORS

Fig. 4-1 illustrates a simple form of relaxation oscillator. When S1 is closed, V1 cannot fire until the voltage across C reaches the breakdown voltage. C is charged through R_s, and this time constant is a major factor in determining the frequency. When C charges to the breakdown value, V1 will ionize and C will discharge through the gas tube to a value referred to as the dynamic extinguishing voltage E_{ext}. V1 then turns off and the cycle repeats. R_s must be high enough in value to inhibit ionization or V1 will continue to stay "On" after C has reached E_{bkdwn}.

Note that only on the first cycle does the sawtooth begin from zero volts, and thereafter it varies from E_{bkdwn} to E_{ext}. Since T represents only a portion of the RC time constant

($R_s \times C$), the actual frequency of operation will be higher than the calculated, ($1/R_s \times C$).

Power supply voltages are equally as important as R_s and C in determining frequency. If the supply voltage E_{app} is raised, the breakdown voltage will be shifted to a steeper portion of the charging curve and V1 will fire sooner, thereby raising the frequency. This, of course, will also improve the linearity of the sawtooth. If the supply voltage is too close to E_{bkdwn}, erratic operation will result. Small tube variations can produce large frequency changes when operation is on the upper part of the RC curve.

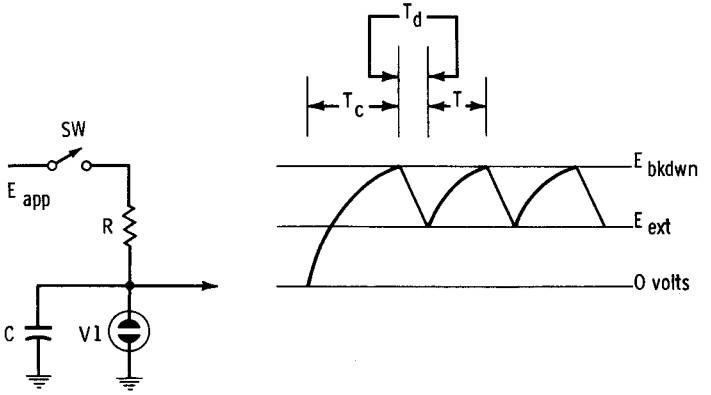


Fig. 4-1. Relaxation oscillator.

The dynamic impedance of the neon tube, the differential between E_{bkdwn} and E_{ext}, as well as the value of C, will determine T_d or the capacitor discharge time. At lower frequencies this value is negligible, but it is a major factor over 1 kHz. The formula for the approximate frequency of oscillation is:

$$f = \frac{1}{2.3\ RC \log \frac{E_{app} - E_{bkdwn}}{E_{app} - E_{ext}}}$$

Precise frequencies are best obtained by trial and error.

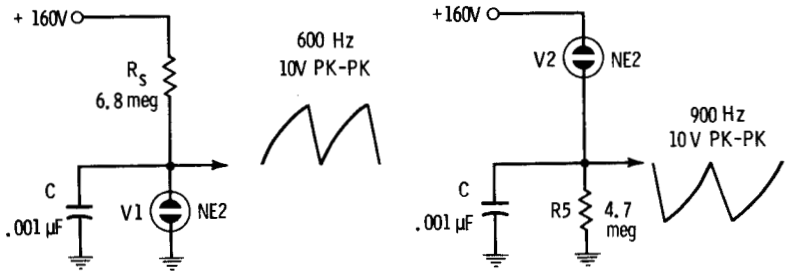
Sawtooth amplitude is basically a function of the neon tube differential voltage or E_{dif}, which is $E_{bkdwn} - E_{ext}$. This also changes with frequency and the value of series resistance. Large values of series resistance tend to lower the dynamic extinguishing voltage.

For a more thorough mathematical approach to neon-lamp oscillators, the reader should refer to the GE glow-lamp manual.

One of the main objections to gas-tube oscillators has been the wide variation in tube parameters and changing electrical characteristics. Tolerances as close as 1 percent for 20,000 hours are now available, and even tighter specifications may be had, but the life expectancy figures on all these types are not yet complete.

In the following discussion it can be noted that NE2 and other indicator-type lamps are used frequently. This is done because the circuit designer and experimenter usually have these types available. Other lamps with closer specifications and no emissive coating on the electrodes would certainly be a better choice for long-term reliability.

Fig. 4-2 demonstrates two variations of the same basic oscillator. The 600-Hz sawtooth at 4-2A would be useful in a noncritical audio application such as a utility signal generator modulator. A simple change in circuit configuration produces the waveform in Fig. 4-2B. R_s was reduced in value to increase the frequency to 900 Hz. The steep wavefront of the inverted and reversed sawtooth might find applications in triggering circuits.



(A) Standard waveform. (B) Inverted and reversed waveform.

Fig. 4-2. Variations in a sawtooth oscillator.

An improved triggering circuit is shown in Fig. 4-3. When the NE2 ionizes, current flow through the 10K resistor reaches maximum in less than 10 μs. It then decays at an exponential rate determined by the RC time constants.

The amplitude of the trigger pulse is dependent on the value of cathode resistance R_k. The exact value of R_k is not critical

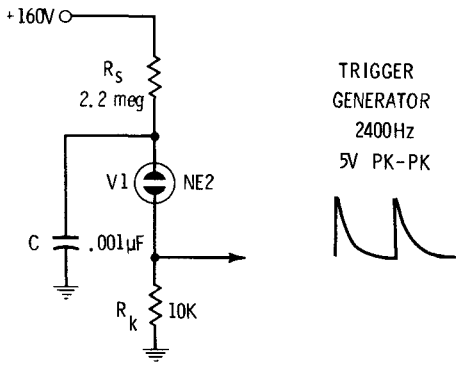


Fig. 4-3. Waveform generator with regulated supply.

and may be varied over a wide range to suit circuit requirements.

A regulated supply may be combined with Fig. 4-3 to produce the waveform generator in Fig. 4-4. The regulated supply voltage is furnished by R_s, V1 and V2. R_{ss}, R_{sss}, C1, and V3 are the major frequency-determining elements, while R_k is used to develop the trigger voltage that appears at point B. Differentiating network, C2, X1, and R_d, provides a 1-μs positive pulse at point C.

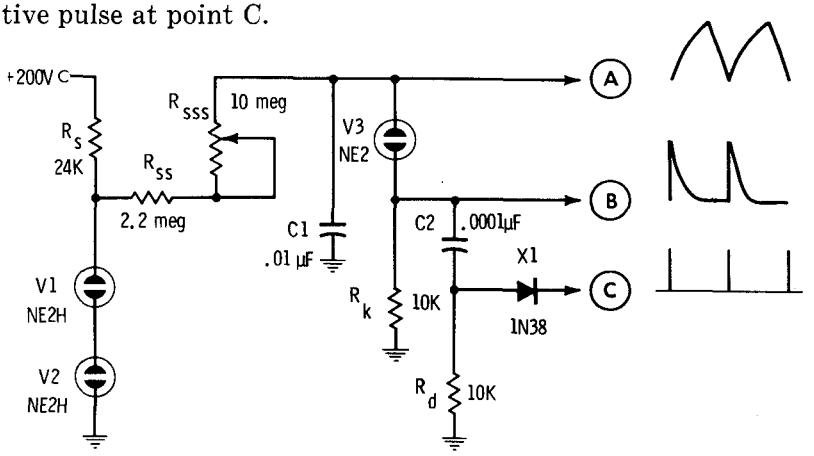


Fig. 4-4. Stable VFO, 40-180 Hz with multiple outputs.

Sometimes it is desirable to have the oscillator synchronized as in Fig. 4-5. Normally R_{ss} is adjusted to a frequency that is slightly lower than 1 kHz, and the wiper of R_k is advanced until the oscillator "locks in." The sync pulse should be at least

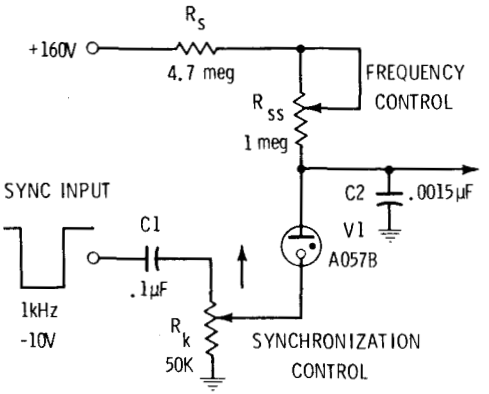


Fig. 4-5. Synchronized 1-kHz oscillator.

50 μs wide, but it can be considerably less than the 10 V illustrated.

A definite rounding of the sawtooth occurs as the frequency increases. This effect is noted because the ionization time, the deionization time, and the avalanche time now represent a larger portion of the total period. If the frequency continues to increase, the gas tube will eventually develop sine wave oscillations. The frequency at which this happens varies for different gas mixtures and pressures, but all occur over 10 kHz. These oscillations are quite unreliable and depend on critical circuit values.

The experimental circuit in Fig. 4-6 was developed in an attempt to increase high-frequency reliability. A power supply tolerance of 10 percent is required but all other values are 20 percent. The LPA 27 has a gas mixture with the fastest avail-

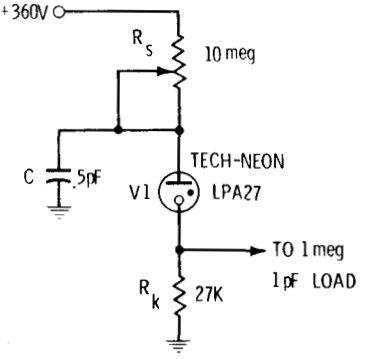
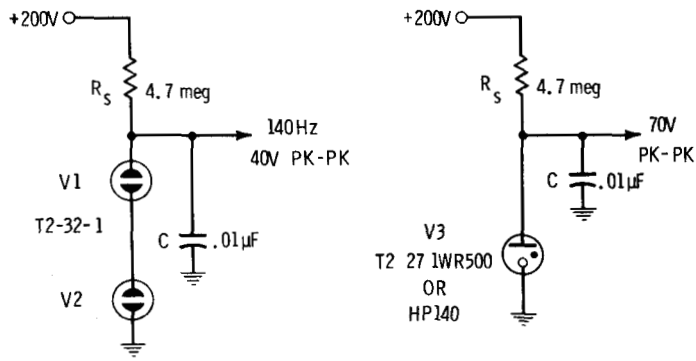


Fig. 4-6. High-frequency sine-wave oscillator, 30-40 kHz.

able deionization time, and is the best choice for high-frequency oscillators and waveform generators.

Deionization time is the limiting factor in reaching higher frequencies. It might be said that anything encouraging ionization will inhibit deionization. The use of lamps having radioactive additives and emissive materials on the electrodes should then be avoided in attempting to get stable high-frequency operation.

Actually frequencies up to 90 kHz have been achieved but the circuit parameters are too critical to be of any value. The amplitude of the sinusoidal wave is difficult to predict. It will, however, be quite small, ranging in value from 1 to 14 volts.



(A) Using two lamps. (B) Using one lamp.

Fig. 4-7. High-amplitude sawtooth generators.

If a high-amplitude sawtooth is required, the modes used in Fig. 4-7 can be tried. When two lamps are connected in series as in Fig. 4-7A the differential voltages will add to produce a double-amplitude sawtooth. As many lamps as desired may be connected in series, but since breakdown voltages also add, the circuit has certain practical limitations. This type of oscillator has found applications in electrostatic deflection systems and relay energizers.

Fig. 4-7B uses a single lamp that has a considerably larger differential, and is satisfactory in most cases, but the inherent instabilities of high pressure gas exclude it from many critical timing circuits. The T2-27-1WR500 will exhibit "voltage jumps" that are visible to the eye. The corona will jump from one part of the cathode to another, causing variations in the

maintaining voltage. These high pressure types (large differential), are best suited for "one-shot" operations, such as timers, relay energizers, and counters.

TWO-LAMP MULTIVIBRATORS

Two neon lamps are frequently used to form a multivibrator circuit. Fig. 4-8 illustrates the basic astable type which has a peak-to-peak output voltage that is twice that of a single tube.

A quick analysis shows that if we assume V1 to be "On" C will attempt to charge to the supply voltage through R_{ss}. When point A reaches the breakdown voltage of V2, the lamp will fire and the voltage at point A will be the maintaining voltage of V2. The negative pulse generated by the drop in potential is coupled through C to B, where it extinguishes V1. Now point B begins to charge up while point A remains at the maintaining voltage of V2. When V1 fires, the process repeats, coupling a negative pulse that is equal to the differential voltage of V1 to point A.

Since multivibrator circuits use two gas diodes, the upper frequency limit is about 8 kHz. This is because the deionization time limitations of both tubes are additive. Manufacturers rarely incorporate gas tube multivibrators that operate over 2 kHz.

At very low frequencies, they are sometimes called flashers and may be used for their visual effect. The amount of light given off by the flash of a neon oscillator is determined by the capacitor and the tube differential voltage. An increase in the value of either one will raise the light output.

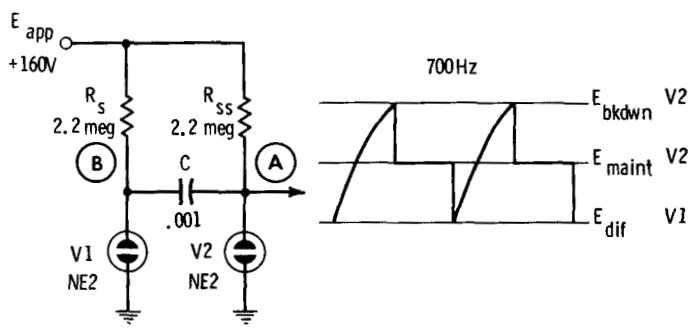


Fig. 4-8. Basic astable multivibrator.

When the multivibrator is not being used as a flasher, R_s and R_{ss} should be as low in value as possible. This not only lowers the output impedance but prevents parasitic oscillations. If capacitances as small as 1 pF exist across the lamp, oscillations are possible with resistor values over 2 megohms, assuming that rectified line voltage is used (+160 Vdc).

Lower value supply voltages allow for the use of smaller resistances and a larger C. An ideal supply voltage is considered by some to be one that exceeds the maximum rated E_{bkdwn} by 30 percent. If the supply voltage in Fig. 4-8 were reduced to 100 V and the two 2.2 meg resistors were changed to 510K, the circuit would oscillate dependably at approximately 2 kHz, and would be free of parasitics.

General Electric recommends that R_s and R_{ss} be below 1 megohm. This is not possible if high-frequency (over 500 Hz) operation from a high voltage supply is required. An effective alternative is to operate the oscillator from a regulated supply as in Fig. 4-4. This calls for two more lamps and a resistor, or a single neon regulator such as the Z100R12 and resistor.

The results that are pictured in this book using any of the "NE" lamps were achieved by selecting lamps having average characteristics. Pre-aged and selected versions, such as the 5AB series, would be a better choice, but tubes without emissive coating, such as the 55ST2A, would be recommended if long term reliability is needed.

If we assume that both lamps are identical, and the series resistors have the same value, the formula for frequency is:

$$f = \frac{1}{2RC \ln \frac{E_{app} + E_{bkdwn} - 2E_{maint}}{E_{app} - E_{bkdwn}}}$$

where,

ln is the natural logarithm.

The modified multivibrator in Fig. 4-9 has two cathode resistors and produces three symmetrical waveshapes. A triangular wave is available between points A and B and has found use as the sweep voltage in some X-Y recorders. The nearly square wave found at point B has a rise time well under 10 μs, and the sloping top may be made flat by using the diode clipper shown in Fig. 4-10.

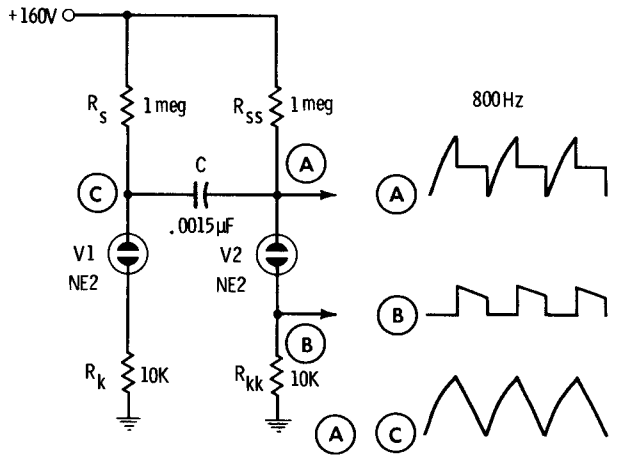


Fig. 4-9. Modified astable multivibrator.

Diode 1N38 has a positive bias of approximately 5 volts on its cathode so it will not conduct until the square wave across R_{kk} exceeds this value. When the diode conducts, clipping occurs and the amplitude of the pulse is clamped to this 5-volt level. The 1-meg linearity control is used to adjust the pulse width.

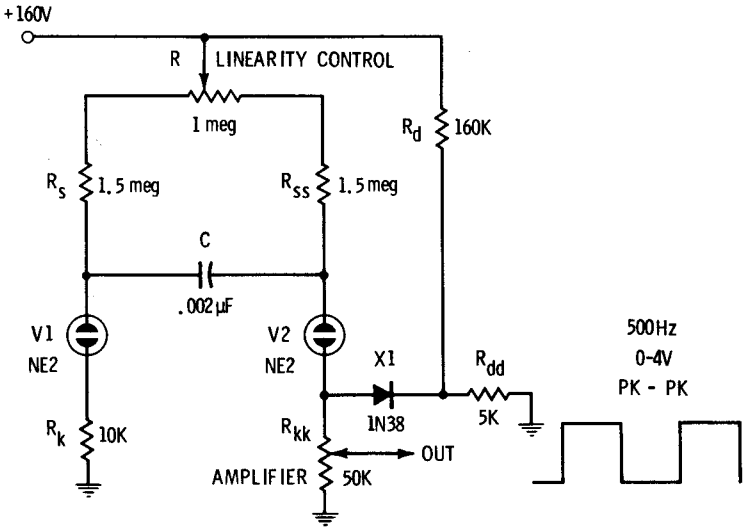


Fig. 4-10. Square-wave generator.

Perhaps the simplest way of producing a high multivibrator frequency is to use a common-cathode resistor. Fig. 4-11 shows the waveshapes available from this type of circuit. The discharges of both V1 and V2 are felt across R_k and a reversed sawtooth occurring at twice the multivibrator frequency is developed. Note that only on alternate cycles is the amplitude equal. This is the result of the differences between the differential voltages of V1 and V2. Varying the frequency control R_k, will also affect the amplitude.

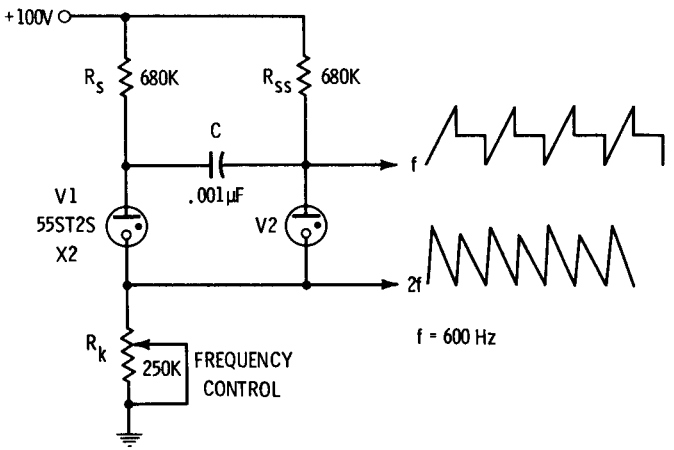


Fig. 4-11. Frequency-doubled, cathode-coupled, astable multivibrator.

The 3-range triangular-wave generator in Fig. 4-12 may be used as a time base for any slow-scan device that needs equal trace and retrace time. It is an astable multivibrator with the components on the ground side of the neon lamps. The output is taken from the 220k resistors, which aid in lowering the output impedance. R_k and R_{kk} also provide a minimum amount of resistance when R_{ss} and R_s are at zero ohms. The 500k potentiometers may be ganged together as a frequency control, or isolated so the linearity may also be adjusted.

FLASHERS

Neon-lamp oscillators are sometimes used as "flashers," which are on/off light sources that are found in signs, toys, and advertising displays. The flasher circuits shown in this

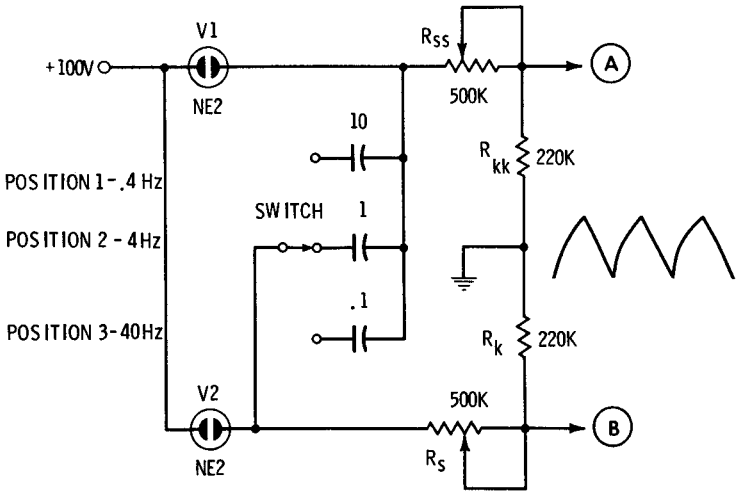


Fig. 4-12. Multirange, triangular-wave generator.

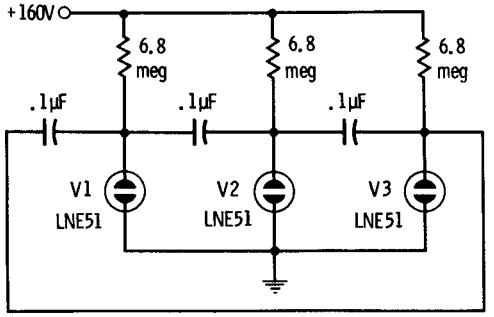


Fig. 4-13. Sequential flasher. Flashing order 1:2:3 or 3:2:1.

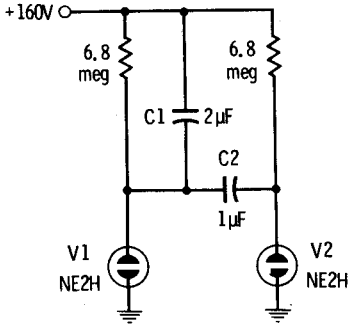


Fig. 4-14. Sequential flasher. Flashing order 1:2:2:2:1:2:2:2.

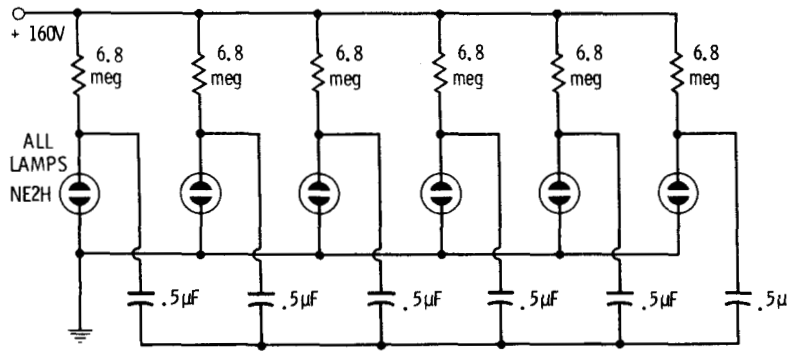


Fig. 4-15. Random flasher.

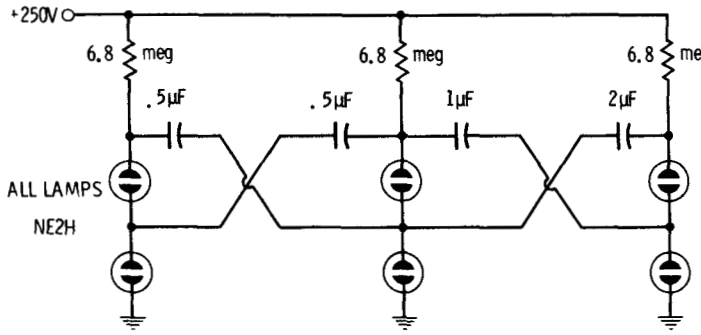


Fig. 4-16. Random flasher.

book only touch on the possible configurations. A little experimentation will provide the user with endless variations.

Fig. 4-13 shows a flasher that will establish a regular sequence, but initially the director of rotation cannot be predicted. Once the pattern is established, it will not change unless the power is removed and reapplied.

Another type of sequential flasher is illustrated in Fig. 4-14. The sequence can be changed by varying C1 or C2. This flasher is quite bright, as large values of capacitance are used.

The random flashers shown in Figs. 4-15 and 4-16 provide an interesting pattern of blinking lights. The behavior of these circuits is unpredictable. Even though each lamp is related to each other lamp mathematically, the end result defies explanation. Fig. 4-16 may be considered an improvement over Fig. 4-15, in that it uses fewer parts and has the same number of lights.

5

Computer Circuits

Neon lamps are currently finding use in low-speed logic circuitry. They are particularly useful in high-level applications where the larger voltages are used to control thyratrons, relays, etc. In addition, the neon provides a visible indication of state, which in many cases eliminates the need for a separate visual readout device.

BISTABLE MULTIVIBRATOR

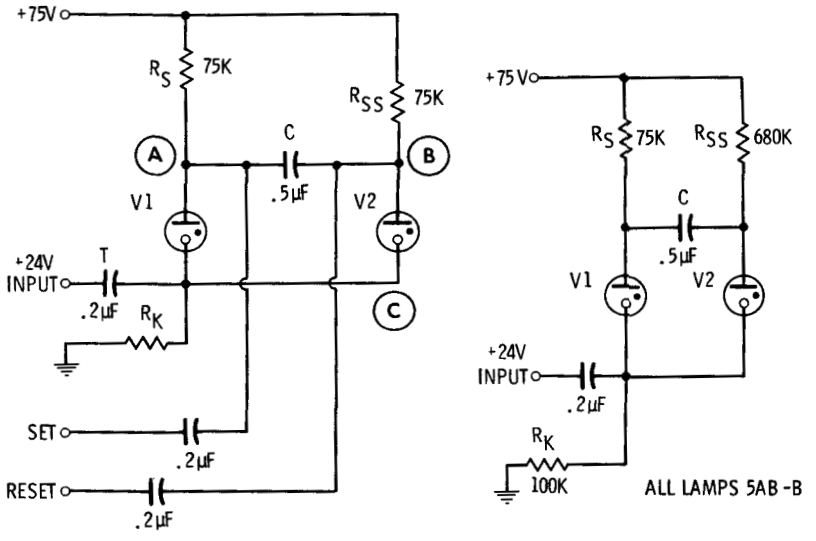
The bistable multivibrator or flip-flop is considered the basic binary computer circuit. Fig. 5-1A shows a gas-tube version of this multivibrator with set and reset functions.

Initially, a zero potential is applied to the reset input. This ground potential is coupled through the .2-μF capacitor to point B and if V2 is conducting, it is extinguished. Since there is nothing to inhibit V1 from ionizing, it will fire, causing a voltage drop to be developed across R_k. When V2 was extinguished, point B increased to the full 75 volts, which would again cause ignition if it were not for the positive voltage at point C developed by the common cathode resistor.

The voltage at point C is determined by the dividing action of series circuit R_k, V1, and R_s. V1 drops its characteristic maintaining voltage (50-60V) and the remaining potential will be divided by R_k and R_s. Increasing the value of R_k will place V2 further into cut-off and allow the use of 20-percent resistors

but the input pulse amplitude must also be increased to overcome this bias.

The multivibrator is now in a steady state and the $\overline{1}$ side is lit. $\overline{1}$ is pronounced "not one" and indicates that no counts are recorded in this circuit. Similarly $\overline{2}$ and $\overline{4}$ are pronounced, "not two" and "not four," respectively. Flip-flops that are driven by the primary one can register these higher value counts. A 24-volt positive pulse applied to the input will cause the flip-flop to switch and the (1) side will be lit indicating a count of 1. The (1) side will be lit once for every two input pulses which means that the circuit counts by two (binary).



(A) Bistable multivibrator. (B) Monostable multivibrator.

Fig. 5-1. Multivibrator circuits.

A 24-volt positive pulse at point C will extinguish the conducting lamp and, since the nonconducting lamp has the highest anode voltage, it will fire first when the 24-volt pulse is removed. The duration of the input pulse is determined by the time constant of R_k and the .2-μF input capacitor. Switching action is further ensured by the discharging action of the .5-μF capacitor. This capacitor prevents the anode of the extinguished tube from reaching a high positive voltage before the opposing lamp can fire.

Attempts to arrange flip-flops in counting chains without the use of diodes or buffer amplifiers have for the most part been unsuccessful. Careful design and a regulated power supply can produce a two-stage binary counter, but additional stages will almost certainly call for solid-state components.

MONOSTABLE MULTIVIBRATOR

The bistable circuit can be converted to monostable operation by a change in resistance ratios. In Fig. 5-1B, V1 is normally on and V2 is held off by the voltage drop across R_k. A 24-volt positive pulse will extinguish V1 and ignite V2 in the usual manner, but R_{ss}, which is the anode resistor for V2 is large compared to R_k, so the voltage developed at point C is not large enough to hold V1 in cut-off. V1 will again fire and the circuit will return to its stable state. The time that V2 remains on is determined mainly by the time constant of C, R_s, and R_{ss}.

THREE-INPUT *OR* GATE

The circuit in Fig. 5-2 is useful in converting high level logic (+70V), to a value that is useful in solid state circuits (+10V). X is normally at zero volts but will rise to 10 volts if either A *or* B *or* C is +70 volts.

V1, V2, V3, and V4 are normally on and the voltage at point N is lower than the lowest extinguishing voltage of the 5AB-B

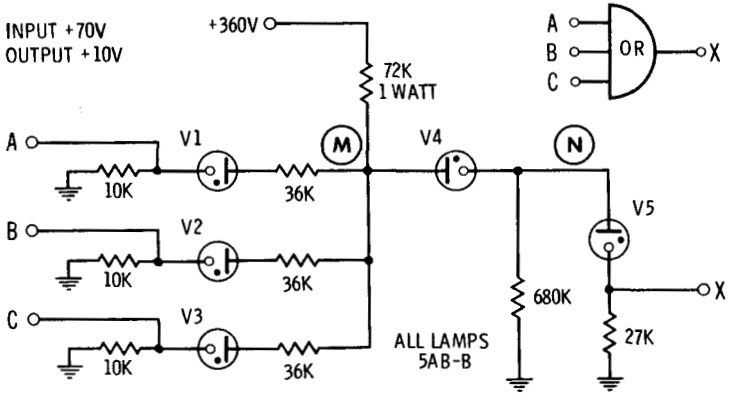


Fig. 5-2. OR gate circuit.

(50 volts). If any of the input lamps are extinguished, the voltage at point M will increase. This will increase the conduction of V4, and the voltage drop across the 680k resistor will reach the maximum rated breakdown value. V5 then fires, and the 10-volt output is taken from the 27k resistor. Removal of the input voltage will cause V5 to extinguish.

THREE-INPUT *AND* GATE

An examination of the circuit in Fig. 5-3 shows that it is basically the OR gate, but with a change in the resistance ratios. The resistance values are so chosen that V1 *and* V2 *and* V3 must be extinguished before the voltages at points M and N rise to a value high enough to ignite V5. If any one of the +70 volt inputs is removed, V5 will extinguish.

If the 72k resistor is removed and the resistor values are again changed, the AND gate can have full dc restoration. Fig. 5-4 illustrates this. The modified gate has a 70-volt output and can be used to operate additional high-level gates. Circuit design is more critical with this type of circuit because the voltage at point M must vary over a range wide enough to break down and extinguish V4 and V5 which are operated in series.

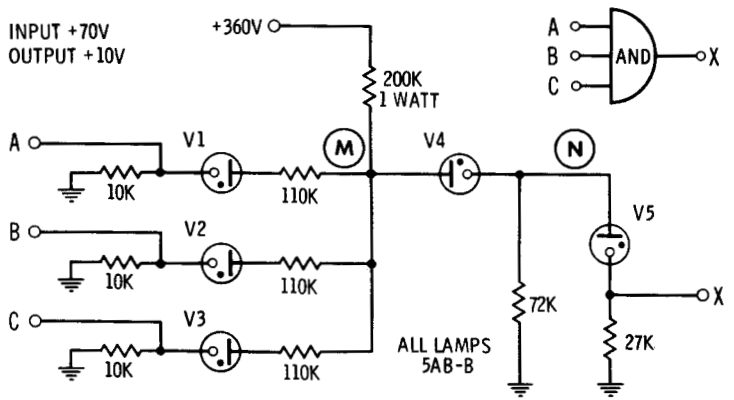


Fig. 5-3. AND gate circuit.

THREE-INPUT *MAJORITY* GATE

Recent concepts in computer logic are making use of the majority gate, which will provide an output whenever the *majority* of the inputs are satisfied.

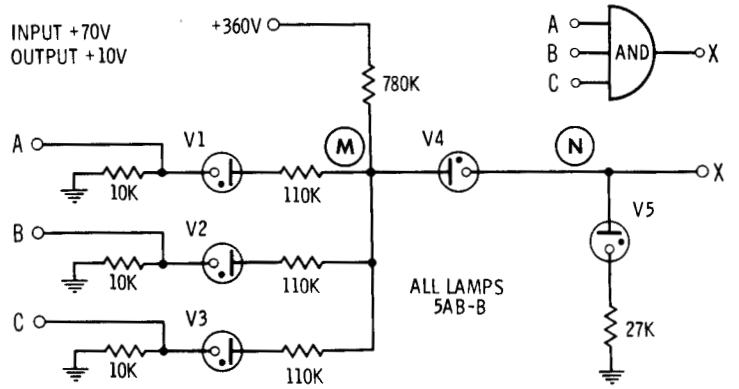


Fig. 5-4. Modified AND gate circuit.

The glow-lamp version in Fig. 5-5 is again the same basic "gate" circuit previously discussed. The resistance values are so chosen as to cause the breakdown voltage of V5 to appear at point N whenever +70 volts appears at any two of the three inputs.

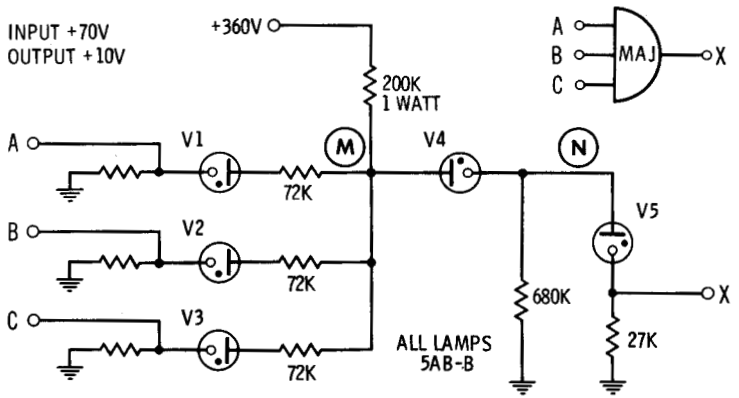


Fig. 5-5. MAJORITY gate circuit.

DESIGN CONSIDERATIONS

Speed is perhaps the most important limiting factor in neon-lamp logic circuits. Flip-flops, monostables, and gates rarely operate over 30 Hz, and delay time for some gates may be as long as 3 milliseconds.

Low series resistances should be used to prevent parasitic oscillations and low supply voltages will prevent free running operation of cathode-coupled multivibrators.

A relay coil is sometimes substituted for one of the series resistances in the flip-flop or monostable circuits. If this is done, lamps with a high differential voltage should be used.

If a circuit is to use off-the-shelf lamps that require no additional testing, consideration should be given to the minimum and maximum voltage rating as given on the specification chart. The 5AB-B was chosen in many circuits because it has a 10-volt breakdown and 10-volt maintaining voltage range. A voltage range this narrow is usually quite easy to work with. The ranges do not overlap and an extinguishing voltage test is included in the manufacture. The 5AB-B is also one of the lowest cost circuit components available.

RING COUNTER

Perhaps the most useful of all the glow-lamp logic circuits is the Manley-Buckley ring counter. It uses the decimal counting system and can easily count to 999 without a buffer amplifier. Counting rates of 500 Hz are possible and since there are 10 lamps for each decade, the lamps themselves can be used for visual readout.

The basic circuit is illustrated in Fig. 5-6 and represents the first three stages of a decade. When the reset button is depressed, the ground return path is removed from all stages but the first, and V0 will fire, indicating a count of zero. Current flow is now through R_s, V0, D1, and R1. V0 will drop its characteristic maintaining voltage (60-70V), and the remaining voltage is dropped by R1 and R_s. This means that the potential at point A can be anything from 92 to 100 volts, which is well below the firing voltage of the T2-27-WR500, so V1 and the lamps that follow are held in a non-conducting state. When the reset button is released, point B, which varies from +29 to +33 volts, will charge C1 to this value through X2. If an input pulse of zero volts is applied to point A through the .1 μF capacitor, V0, which was conducting, will now be extinguished. The voltage at point A will again begin to go positive as C_x attempts to charge to the supply voltage through R1. V1 will be the next lamp to fire and will reach breakdown before point

A reaches 110 volts. This action occurs because C1, which has a 30-volt charge, cannot discharge through X2 when V0 goes out. Instead it makes the cathode of V1 30 volts more negative than the remaining lamps, which assures earlier breakdown. When V1 fires, the process is repeated and C2 becomes charged to fire the next stage.

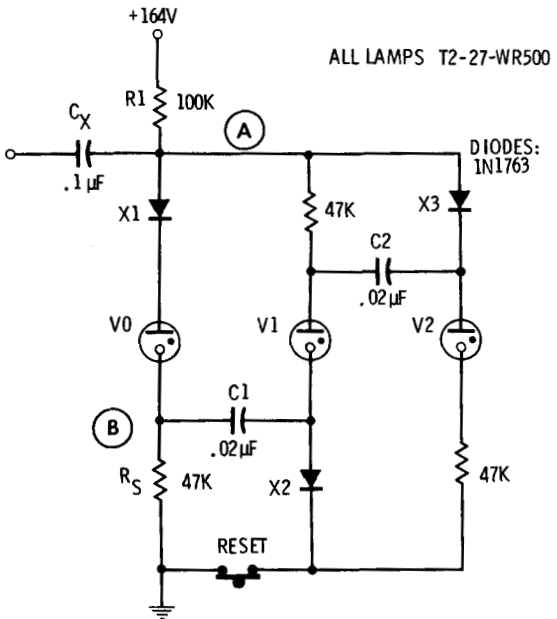


Fig. 5-6. Manley-Buckley ring counter.

The T2-27-WR500 lamps were chosen for this circuit because they have a large differential, which allows the use of 10-percent resistors and a non-critical power supply. The lamps in the illustration are operated at lower currents in order to decrease their deionization time.

Gas tubes with a smaller differential, such as the 5AB series, NE2, etc. are capable of faster counting rates, but the lamps must be electrically matched and the circuit calls for tighter resistor specifications. The 5AB type does, however, have greater light output, which can be important if the lamps are going to light numerals on a display panel.

Point A must be held below the rated extinguishing voltage for a period long enough to allow for complete deionization.

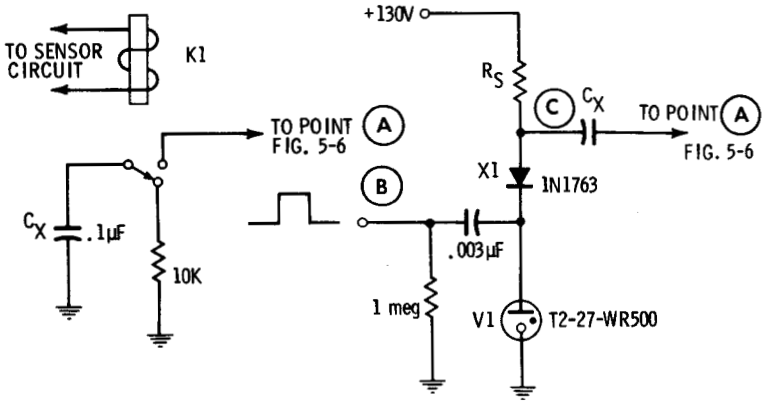
The time it takes point A to reach any given value is determined by the time constant of C_x and R1.

Deionization time can be decreased if point A is not brought all the way to zero volts but to some point more positive. This value varies for different lamp types, so it is found experimentally.

TRIGGER CIRCUITS

The ring counter in Fig. 5-6 was triggered by applying zero volts to the .1-μF input capacitor. When the circuit is stabilized, the voltage at point A is approximately 100 volts and the input capacitor is charged. C_x must be discharged before another count will be recorded; Fig. 5-7A shows one basic method for accomplishing this.

The form C contacts of K1 allow C_x to be connected to point A of Fig. 5-6 when the relay is operated. The sensor circuit, which may be simply a switch, will operate the relay whenever a count is to be recorded. When K1 is released, C_x will discharge through the 10k resistor and the circuit is ready for another cycle. The 10k resistor is for contact protection and should be small enough in value to allow for complete capacitor discharge. The speed of this circuit is restricted mainly by the operate and release times of K1. It is not practical to operate most relays over 50 Hz so the circuit in Fig. 5-7B can be tried for higher counting speeds.



(A) Switched capacitor. (B) Gas tube.

Fig. 5-7. Basic decade ring triggers.

Gas tube V1 is operated under its minimum breakdown value and is triggered on by a positive pulse at point B. This causes a drop in potential at point C of at least 60 volts. The negative pulse is felt at point A through C_x and the conducting tube in the ring circuit is extinguished. C_x and R1 of Fig. 5-6 must now have a longer time constant since the voltage at A does not drop as low as it did with switched capacitor operation.

Point A again starts to rise in voltage and continues until the next tube in the ring fires. This new ignition causes a drop in potential at point A that is coupled back through C_x to point C of Fig. 5-7B. This negative depression should be enough to extinguish trigger tube V1 and reset the entire circuit for another count. This type of circuit can be used for inter-decade triggering, thereby eliminating the need for buffer amplifiers.

A practical circuit that is operated by switch closures is shown in Fig. 5-8 and was designed for the complete ring counter shown in Fig. 5-9.

The .001 μF capacitor is charged to about 45 volts by voltage-divider action and when the count button is depressed, the rapid drop in potential at point B will cause C to attempt to discharge. Since X1 blocks one discharge path, the −45 volts is felt on the cathode of V1 and causes ionization. R1 in the counter and C_x were both increased to the values shown, to lengthen the time constant.

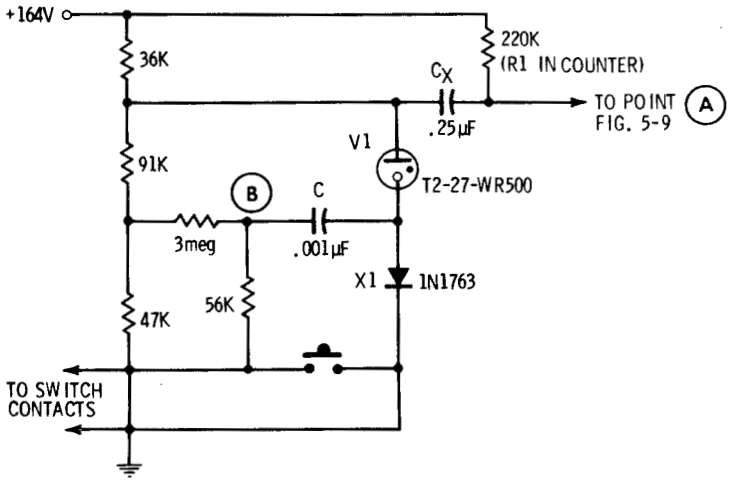


Fig. 5-8. Neon trigger for switch contacts.

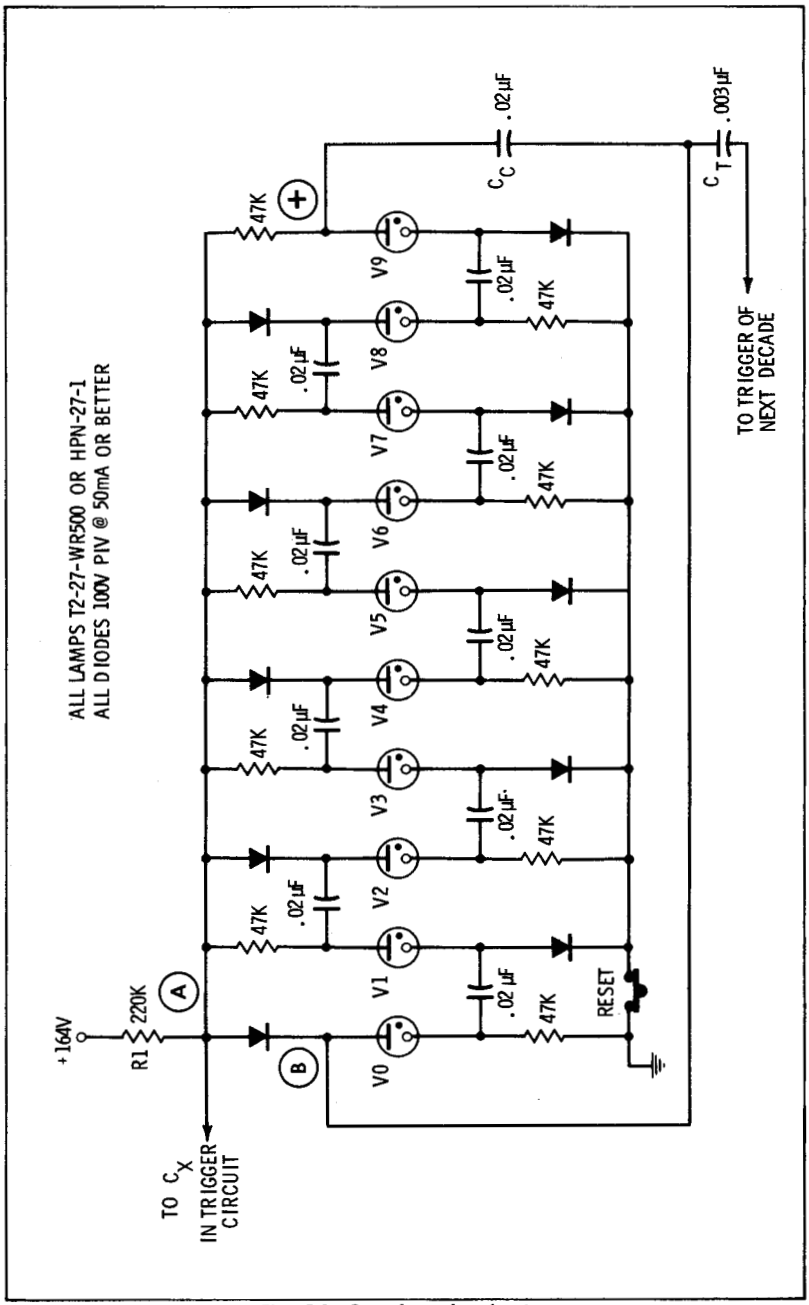


Fig. 5-9. Complete decade ring.

COMPLETE DECADE RING

The decade illustrated in Fig. 5-9 has ten identical stages, as discussed earlier. It also has a carry function that permits the decade to be reset to zero and operate the trigger stage of the following decade.

When V9 is extinguished by the tenth pulse, the rise in potential at point (T) is coupled through C_c to the anode of V0 and through C_c and C_t to the trigger stage of the next decade.

Two Z82R10 miniature neon regulators operated in series will provide a regulated 164 volts ±2 volts for the counter and trigger circuits. An eight-decade counter can be operated from these two tubes, thereby eliminating complex circuitry. The power supply potential is not critical, but it must always exceed the lamp maximum-rated breakdown voltage.

6

Miscellaneous Circuits

SCR CONTROL

Silicon controlled rectifiers or thyristors are best controlled when they are provided with a discrete trigger pulse. The gate-to-cathode circuit of the SCR in Fig. 6-1 is in series with V1 and the turn-on pulse will be generated when the lamp fires. V1, together with C and R1, forms a one-shot relaxation oscillator that is operated at some point on the positive portion of the 60-Hz sine wave. The exact operating point is determined by the setting of R1, sometimes called the "Speed Control." The value of C is made large enough to supply ample gate current and the neon tube was selected for its 60-mA peak-current capability. Most manufacturers recommend the 1k resistor (R2) for predictable gate turn-on characteristics. The effect of R2 on the oscillator circuit can be ignored.

With the HI-LO switch in the HI position, the negative half of the sine wave is allowed to conduct through the load at socket M1 and the MR990 diode X1. The positive half is controlled by the SCR and oscillator circuit, and since the breakdown voltage of the neon tube represents approximately 30 degrees of the sine wave, the load can never be turned completely on (360 degrees). This 30-degree loss represents little power, so the effects are negligible.

When the HI-LO switch is in the LO position, 30-180 degrees of the ac cycle may be applied to the load. Diode X1 is con-

nected in the reverse direction across the socket, so the conductive path for the negative alternation has been removed.

Diode X1 now becomes a "free-wheeling" diode and helps reduce the "cog-wheel" effect common to motors that are pulsed-on with short bursts of current. This is done by providing a discharge path for the magnetic field that exists in the motor windings when the SCR shuts off. The collapsing magnetic field induces a current through the diode and motor windings that is in the same direction as the original, thereby minimizing abrupt changes in power. X1 also provides the SCR with protection from transient voltages in both positions of the switch.

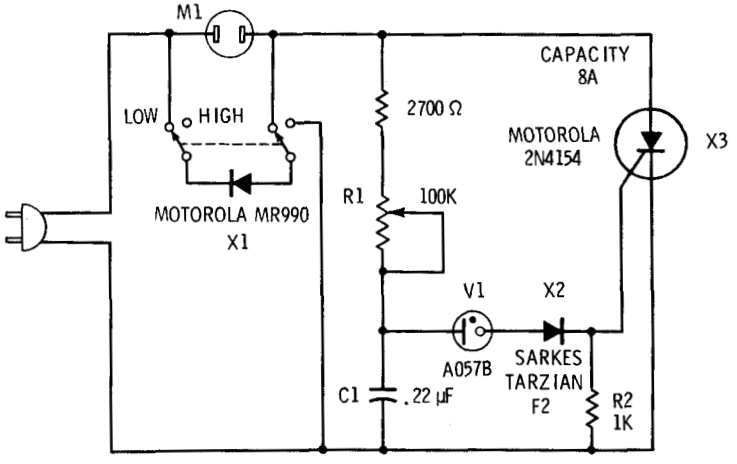


Fig. 6-1. Economy 330-degree SCR control.

RELAY CIRCUITS

Gas tubes have been used to energize relays since the early 1930's, but originally this was limited to thyratrons because of their higher current capabilities. Miniaturization and the mass production of sensitive relays in later years allowed the use of T2 neon lamps.

Most neon-operated relays constitute some part of a threshold circuit. In Fig. 6-2A the minimum rated breakdown of V1 is 140 volts so K1 cannot operate until this potential is reached. When V1 does ionize, it will drop its characteristic maintaining voltage and the remaining voltage is dropped across K1.

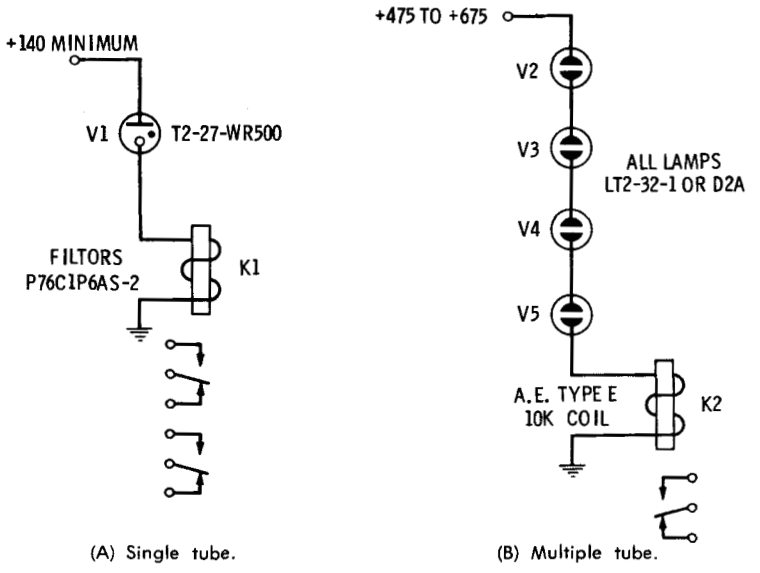


Fig. 6-2. Threshold relay energizers.

This is approximately 75 volts, enough to operate the relay. In effect, the relay is operated by the differential voltage of the tube, unless the power supply is going to increase to some greater value. The relay will release whenever the dropout current is reached, or when the lamp extinguishes.

Neon lamps may be operated in series to reach higher voltage levels as shown in Fig. 6-2B. Long-cathode indicator types were used in this case because of their lower cost and higher current ratings. Since differential voltages as well as breakdown and maintaining voltages add in a series circuit, a relay was chosen that would operate on the lowest differential and not be damaged by the highest. The Automatic Electric Type E satisfies both requirements and may be used with two form C contacts. The bifurcated contacts are rated at 4 amperes.

Fig. 6-3 illustrates a circuit that uses a sensitive, balanced-armature relay that will operate on less than 2 mA. K1 is in series with V1 and connected across part of a voltage-divider network. The position of the SET control dictates what potential must be applied to point B before point A reaches the lamp breakdown voltage. R_s and the resistance of the coil are low enough to allow pull-in current to flow after breakdown.

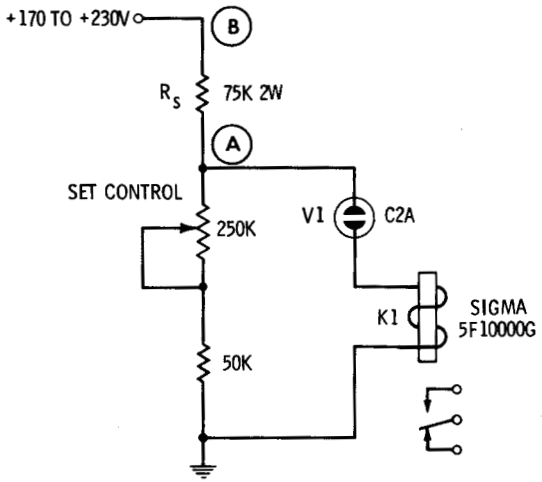


Fig. 6-3. Variable-threshold circuit.

Larger relays may have pull-in currents as high as .5 ampere. If threshold operation of these types is needed, the circuit in Fig. 6-4 can be tried.

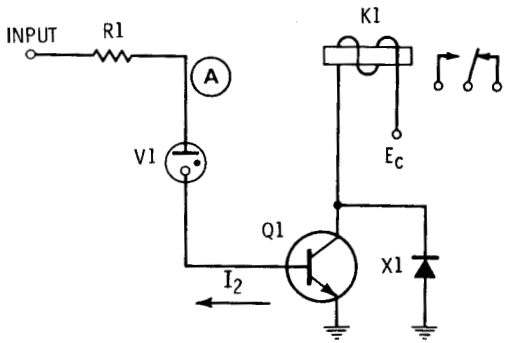


Fig. 6-4. Transistor-drive threshold relay.

A transistor should be chosen that can furnish the relay operating current and withstand the power supply voltage E_c. Low-leakage silicon types would be a good choice for the circuit shown, since the base of Q is not returned to ground.

E_c can be any value above the rated relay voltage but excessive voltages will increase the amount of power dissipated by Q.

To find I_2, use the formula:

$$I_2 = \frac{\text{Relay current}}{\text{Transistor beta}}$$

To find R, use the formula:

$$R = \frac{\text{Neon differential}}{I_2 \times 2}$$

Diode X1 is included to protect the transistor from the counter emf generated by the relay. Time delays can be incorporated in the circuit by connecting a capacitor between point A and ground.

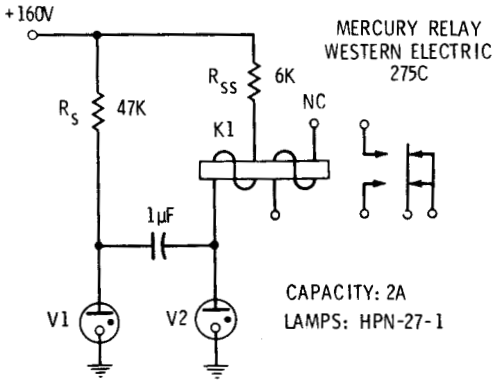


Fig. 6-5. Power flasher, 3 PPS.

A mercury relay is used in the multivibrator circuit of Fig. 6-5 for extended life (over 1 billion operations). The high resistance coil is used for increased sensitivity and is operated by V2. The ratio of R_s to R_{ss}, and the relay coil resistance (3300 ohms), were chosen to keep the relay de-energized five times longer than it is energized.

Fig. 6-6 shows one variation of a memory or latching circuit. V1 is held below its minimum breakdown voltage and cannot ionize until a negative pulse of sufficient amplitude is felt on the cathode. The potential difference between this pulse and the supply voltage must equal the maximum rated breakdown voltage of the tube.

The circuit will "remember" a switch closure when the .001-μF capacitor discharges through the 56k resistor, the

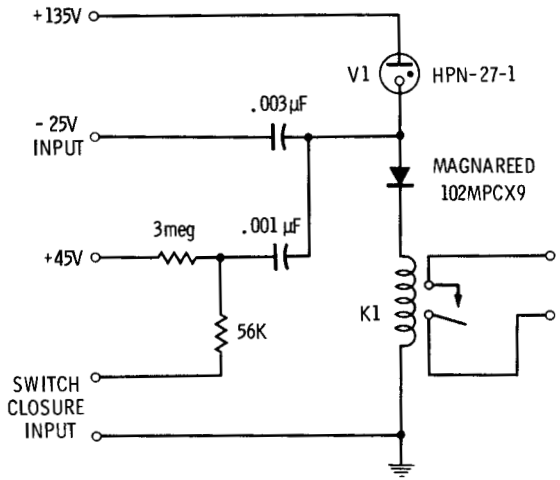


Fig. 6-6. Relay memory.

switch contacts, and the tube to produce breakdown. Diode X1 prevents the capacitor from discharging through the coil of the reed relay, which would inhibit firing by providing a shunt path. X1 can be any commercial-grade component with a 200-PIV rating. The supply voltage is high enough to sustain ionization, so the current flow through V1, X1, and K1 will keep the relay energized until the +135-volt supply is removed.

PHOTOCELL CIRCUITS

Photoconductive cells that operate on the bulk effect are usually made of cadmium selenide (CdSe), or cadmium sulfide (CdS). Both materials can be considered as a pure resistance whose ohmic value depends on the amount of light falling on its surface.

CdSe and CdS cells can each be operated by glow lamps, but CdSe has a peaked response in the 7000-angstrom region, so it is more sensitive to the light radiated by the ionized neon gas. Greater efficiency is obtained by using high brightness lamps that produce more lumens per milliampere.

Most of the lamp-photocell combinations discussed in this chapter are mounted end-to-end as in Fig. 6-7B. The cell is placed in the tube and the end is sealed with silicon rubber. The neon lamp is then put in the other end and should touch

the photocell before the sealer is applied. Since this makes a moisture-proof, light-proof module, lamps are used that have been compensated for dark-effect.

Clairex *Photomods* and Raytheon *Raysistors* have similar mounting schemes providing over 1000 megohms of isolation between the lamp and photocell.

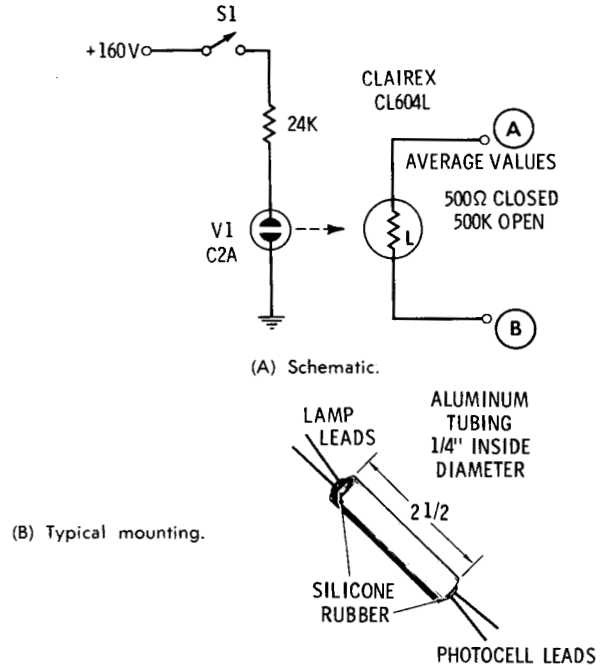


Fig. 6-7. Isolation photoswitch.

Fig. 6-7A is an isolation switch that has a contact resistance of 500 ohms. It is operated by the light from V1 when S1 is closed. The noise and transients associated with mechanical switches are minimized since there is no contact bounce and the photoconductive material does not change state rapidly. This latter feature is useful in interrupting inductive loads.

The lamp-photocell module has also been used as a voltage-controlled resistor. In Fig. 6-8 a 2.3 to 1 voltage change can produce a 5 to 1 resistance change. A more popular version of this circuit is the current-controlled resistor or "isolation potentiometer." R_s is replaced with a 250k potentiometer and the current of V1 is varied to produce the desired output value.

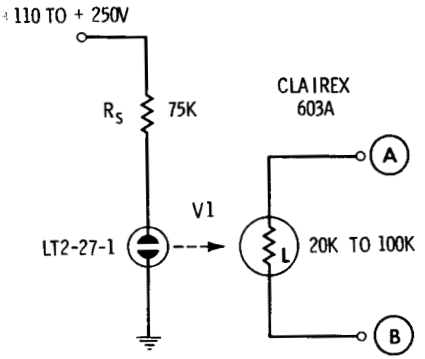


Fig. 6-8. Voltage-controlled resistor.

Resistance ratios of 10,000 to 1 are possible, using this method, without the inherent noise of the slider arm.

Photochoppers are similar to relay choppers in that they offer a number of contacts that open and close at some predetermined frequency. The circuit in Fig. 6-9 shows four modules connected to form a 20-Hz astable multivibrator. It can be used to provide synchronous spdt service in voltmeters and

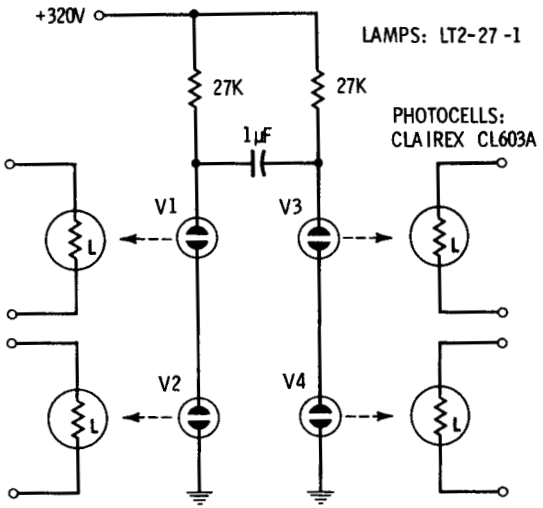


Fig. 6-9. 20-Hz square-wave photochopper.

chopper-stabilized power supplies. Low noise and long life are again the features of this type of circuit. Photochopper frequency is presently limited to 1 kHz maximum. This is due mainly to the response time of the photocell.

A more efficient circuit would eliminate V2 and V4 so the remaining photocells could be mounted in a manner that would have V1 and V3 driving two cells each. The 1-μF capacitor can be removed for 110 Vac operation if diodes are placed in series with the lamps. The diode in series with V1 should have a

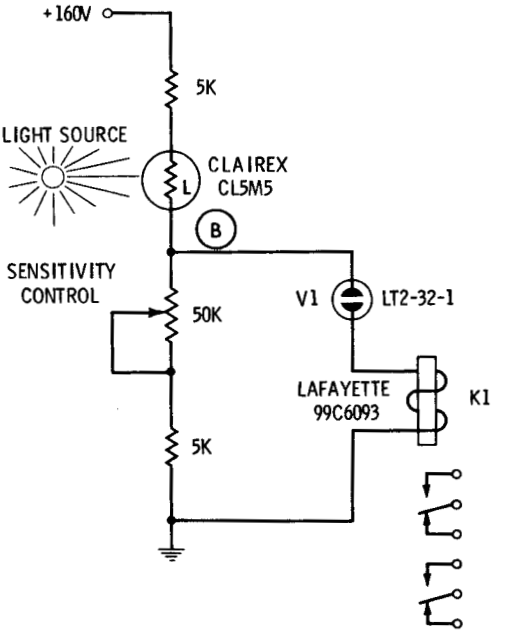


Fig. 6-10. Light threshold circuit.

polarity that is opposite to the one in series with V3. One lamp will conduct when the line goes positive and the other will conduct during the negative alternation. Commercial versions of the ac driven chopper are Clairex CM-2, Leeds and Northrup 854256, and Airpax 5510.

Photocells can be made to operate neon lamps if both are part of a voltage-divider network. In Fig. 6-10 the SENS control will determine how much light must strike the photocell before its resistance is low enough to cause the breakdown

voltage of V1 to appear at point A. A useful variation of this circuit is to interchange the SENS control with the photocell so the relay will be activated by darkness instead of light. The two 5k resistors are protective devices for the photocell.

The circuit in Fig. 6-11 is classified as experimental because it has not been fully developed nor has it found popular use. It demonstrates the little known principle that sine-wave amplification is possible using a wide range photocell in conjunction with a neon lamp.

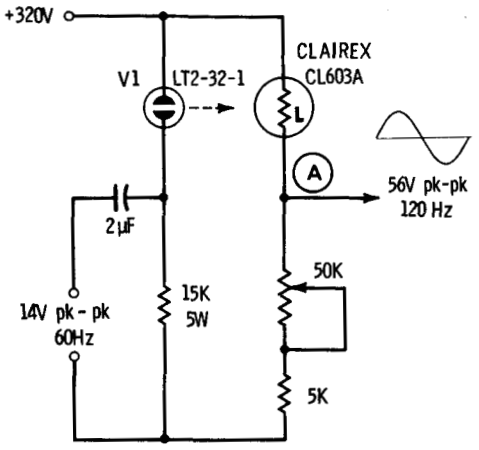


Fig. 6-11. Experimental amplifier/doubler.

V1 is mounted in a light-proof enclosure at right angles to the cell, in order to expose as much electrode to the CdSe as possible. The incoming 60-Hz sine wave is coupled to the 15k resistor through the 2-μF capacitor. This varies the lamp current, causing a modulated light output. The resistance of the photocell varies over a wider ratio than the lamp current, so amplification is possible.

The output is taken from the voltage divider at point A. For maximum amplification, this point is adjusted by the 50k control to half the supply voltage. V1 is operated at very high current, so a short life will result. Perhaps different mounting schemes, such as a cluster of four cells connected in a series/parallel arrangement around the lamp, would result in lower operating currents. Changes in photocell geometry and lens arrangements also might improve the response.

PHOTOCONDUCTIVE JUNCTION DEVICES

Most solid-state component manufacturers now offer a variety of junction devices that can be operated by a gas lamp. The list includes diodes, SCR's, FET's, and transistors. In each case a pn junction is "switched on" by an external light source. The response time of these types is very fast, but higher input-light levels are needed since the junction area is relatively small. Many of these photojunctions have a spectral response peaked in the 8000-angstrom region, so an argon-filled lamp can be used.

TEMPERATURE AND HUMIDITY SENSORS

The light threshold circuit in Fig. 6-10 can be modified to operate on some chosen temperature or relative-humidity level. The photocell is replaced with a thermistor or humidity sensor and the value of the SENS control is selected to match the range of the new device.

TIMER CIRCUITS

Gas-tube timing or delay circuits can be regarded as variations of the basic oscillator circuit. The difference is that the series resistance must be made small enough to keep the lamp ionized after the capacitor reaches striking voltage. Fig. 6-12 illustrates the basic circuit. R_s was chosen to provide the operating current for the relay and to sustain ionization. Under these conditions a delay of over 20 s would call for a 1000-μF, 200V capacitor. A component of this size would be both expensive and bulky, so the approach used in Fig. 6-13 might be more practical.

V1, K1, V2, and X1 form a circuit that is similar in many ways to a thyratron or even to a unijunction transistor. The ground side would be the cathode, or base 1, and the high side would be the anode, or base 2. Point A would then be the grid, or gate.

The breakdown voltage of both tubes in series is higher than the supply voltage, so the lamps initially are in a nonconducting state and X1 prevents V1 from ionizing through C. When S1 is put in the START position, the voltage at point A will rise

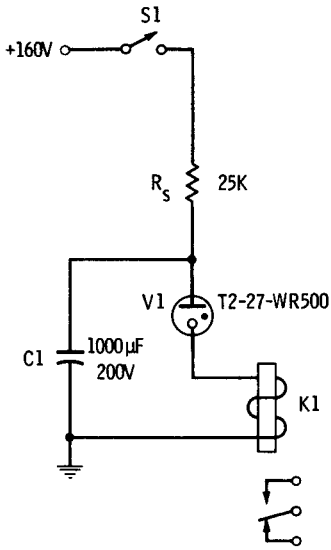


Fig. 6-12. Basic timer circuit.

exponentially until V2 fires. The maintaining voltage of V2 plus the breakdown voltage of V1 is well under the +160V supply so V1 will also ionize and energize K1. The resistance of K1 is 10k, and no additional current-limiting resistor is needed.

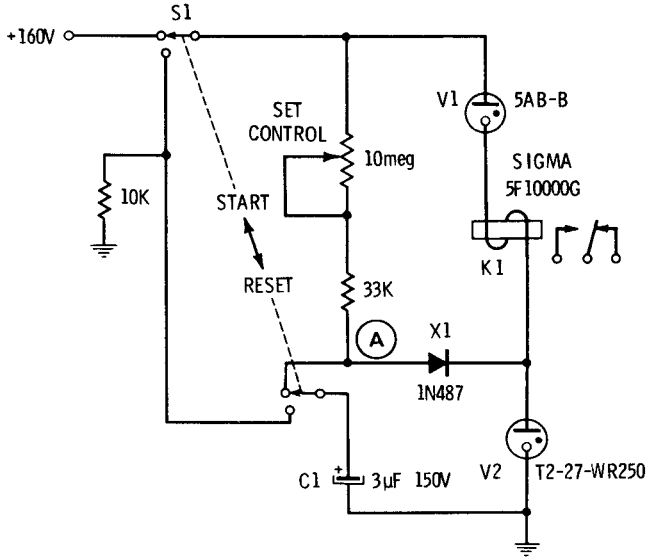


Fig. 6-13. Variable .1 s to 25 s timer.

Unlike the case of the unijunction transistor, the applied power must be removed before K1 will release. This is done by putting S1 in the RESET position and simultaneously discharging C through the 10k resistor.

Fig. 6-14 shows another method of isolating the timing circuit from the operating circuit. Point A is held slightly below the lamp's rated breakdown potential and the tube remains extinguished. When S1 is switched to START, the voltage at point B will begin increasing in value at a rate determined by C and the programmable resistor input. V1 will conduct through isolation diode X1 when point B reaches breakdown. Ionization will be sustained by current flow through isolation diode X2 and R_d.

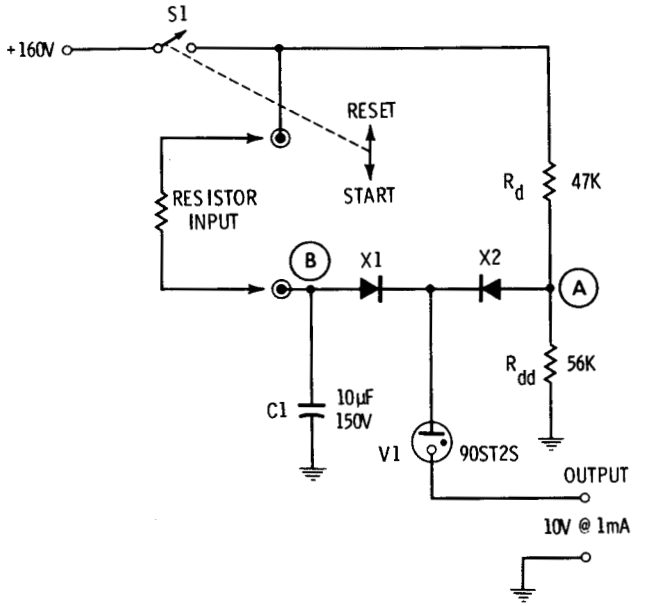


Fig. 6-14. Programmable timer, 100,000 ohms per second.

If the breakdown voltage of V1 is 63 percent of the supply voltage, then it can be said that the tube will fire in one time constant. A 90ST2S was used in this example, but greater accuracy can be had by hand-selecting a pre-aged high-brightness lamp for a 100.8-volt breakdown. The capacitor and resistor values should have a close tolerance and the diodes can be any

replacement-grade component rated for 200 PIV at 100 mA or better.

TOUCH CONTROL

Body capacity can be used to operate the circuit in Fig. 6-15 by briefly providing a conductive path to ground. The circuit consists of a bistable multivibrator that is triggered by bringing the hand in contact with the touch points. X1 is rated at 200 PIV, 100 mA.

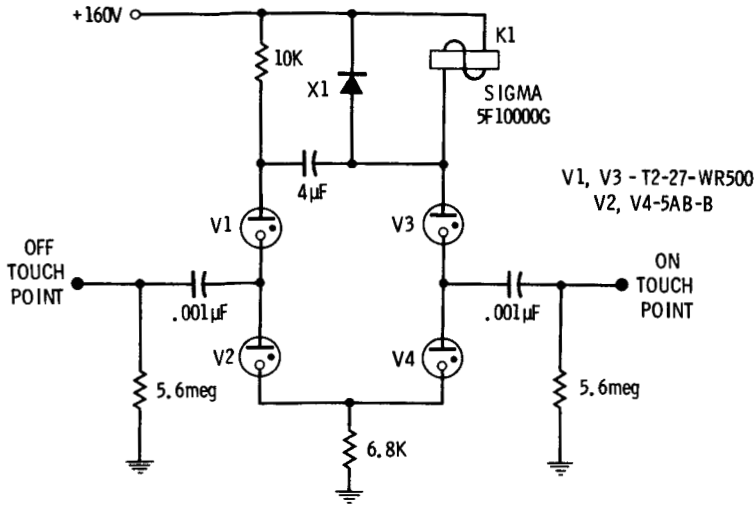


Fig. 6-15. Touch control.

The circuit works well under most conditions, but enough body capacity must exist between the touch point and circuit ground. The earth side of the power line should be connected to the circuit ground if an ac/dc supply is used. If an isolated or battery supply is used, the touch point might have to be made physically larger and the circuit ground should be an actual metal chassis, not a circuit board or terminal strip.

AUDIO SWITCH

V1 in Fig. 6-16 acts as a high resistance in the nonconducting state and prevents the audio from being transmitted to

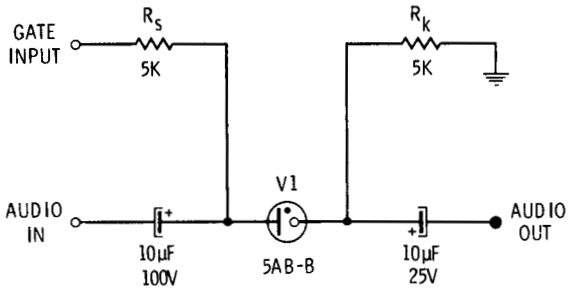


Fig. 6-16. Audio switch.

the output. A +72V level at the gate input will fire V1, and the ionized gas will now act as a low-impedance path for the ac signal.

Miniature neon lamps are cold-cathode devices, so the current flow will change rapidly with voltage variations. The lower frequency response is determined by the value of the coupling capacitors, and the high end is a function of the gas and the current through the lamp. The circuit shown works through most of the audible spectrum, so smaller capacitors can be used for communications channels (300-3000 Hz.).

VARIABLE DELAY CIRCUIT

Transmission time in a gas tube is a function of tube operating current, so changing the value of the series resistance will also change the delay. The ganged controls in Fig. 6-17

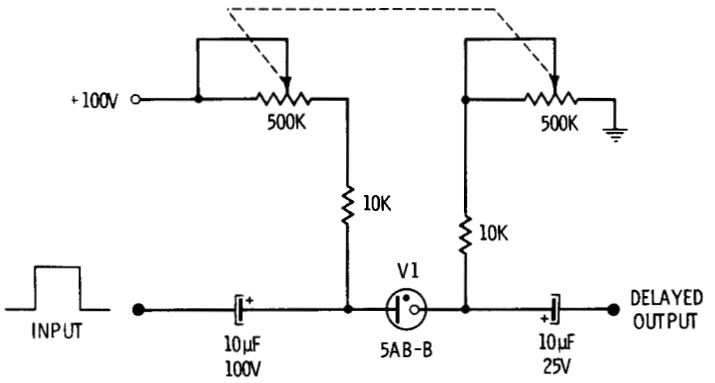


Fig. 6-17. Variable pulse delay.

can be adjusted to give delays over the range shown. Two potentiometers are used in this case to provide an output pulse of constant amplitude.

OVERVOLTAGE CIRCUITS

Arc suppression is usually necessary to protect the device that controls an inductive load. If the current to an inductor is interrupted by switch contacts, the coil will generate a counter emf that may exceed several thousand volts. The exact value of the generated voltage depends on the inductance of the coil and the magnitude of the current. This inductive "kickback" causes arcing at the contacts and leads to a shorter switch life.

High amplitude voltages can, of course, permanently damage semiconductors, so if the switching component is a junction device, the voltage problems still exist. An arc suppression circuit for solid-state components is usually referred to as an overvoltage circuit.

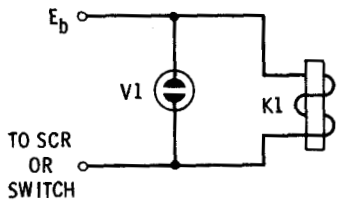
Fig. 6-18A uses a neon lamp to limit to a safe value the emf generated by relay K1. The breakdown and maintaining voltage is chosen to be above E_b so the lamp is normally extinguished until the current to K1 is interrupted. The high backward voltage generated by K1 ionizes V1 and the potential is held to the maintaining voltage of the neon lamp. If a mechanical switch is used to operate K1, then almost any neon lamp will protect the contacts, but again the maintaining voltage in a dc circuit must be above E_b or the lamp will be destroyed after ionization.

High-current relays such as solenoids require special lamps because the collapsing magnetic field in these types can generate enough energy to destroy a simple A1A lamp. Under these conditions, the tube's energy-transfer rating should be considered. In general, the lamp types that can transfer the most energy are the ones with the highest voltage differential.

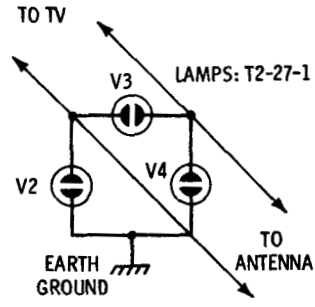
Sometimes, as in dc power supplies, the switch contacts are of little concern and the attention is focused on the solid state components. Silicon and germanium devices have strict voltage ratings that should not be exceeded.

The novel lightning arrester in Fig. 6-18B acts as an open circuit until the breakdown voltage of any one of the three

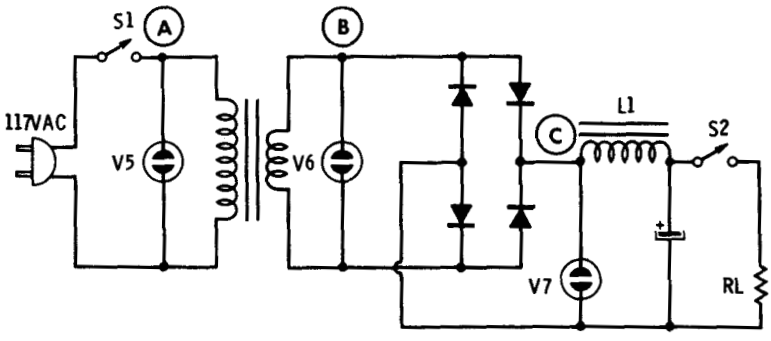
lamps is exceeded. Since no performance data are available, and it is doubtful whether the circuit would provide complete protection against a direct strike, it should only be used in conjunction with a conventional lightning arrester. One application of this device is the protection of TV or radio front ends from nearby transmitters.



(A) Single lamp with relay.



(B) Three-lamp lightning arrester.



(C) Overvoltage protection in a power supply.

Fig. 6-18. Overvoltage circuits.

Overvoltage protection for a typical power supply is considered in Fig. 6-18C. V7 is used to protect the diodes from the counter emf generated by L1 when S2 is opened. This limits the use of V7 to power supplies under 50 volts.

V6 at point B is across the secondary of the transformer and sees only ac, so the maximum rated potential at point B should be around 40 Vac. Point B is a preferred location since it provides overvoltage protection for diodes with a PIV rating as low as 75 volts. The output voltage can be any value under 50 volts. V6 suppresses the high-voltage peaks generated

when S1 is opened and also suppresses high-voltage line transsients.

Probably the most popular suppresser location is point A, which is directly across the primary. The AO51 and HPN-27-1 were manufactured specifically for line-voltage service but other types can be used, such as the T2-27-1WR760 or even two high-brightness indicators in series. The basic requirement is that the breakdown voltage must be higher than the peak line voltage (165V). V5 is effective against transients and lengthens the life of S1, but it does not give the same degree of diode protection from transformer voltages as V6.

7

Power Supplies and Instruments

UNREGULATED 160-VOLT SUPPLIES

Fig. 7-1 shows two power supplies that can be used to operate most of the circuits discussed in this book. The full-wave version is, of course, the preferred circuit, since it has a lower ripple content and offers isolation from the power line. Sometimes a 1:1 isolation transformer is available and full-wave rectification can be had by using a bridge across the untapped secondary. This latter solution is popular for load currents in excess of 100 mA.

REGULATED POWER SUPPLIES

The regulated power source in Fig. 7-2 is made from a half-wave voltage doubler, a neon regulator, and a zener diode. This supply can be used for neon oscillators, timers, ring counters, and other devices that need a stable 160/164 volts.

Vacuum-tube regulators operate by changing their internal resistance when the bias is varied. In Fig. 7-3 both circuits use the maintaining voltage of the neon lamp as a reference for one of the control electrodes, while the other control electrode is connected to a point that reflects voltage changes in output.

Series tube V2 can furnish more power at greater efficiency than shunt regulator V4, since the current through V4 is lim-

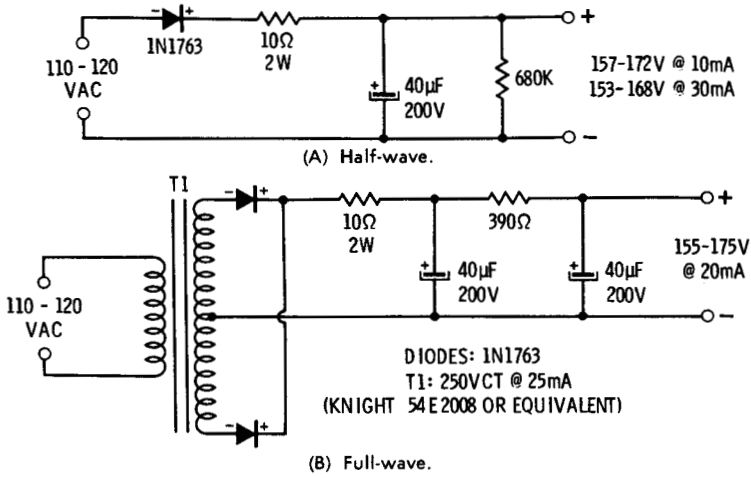


Fig. 7-1. Unregulated supplies.

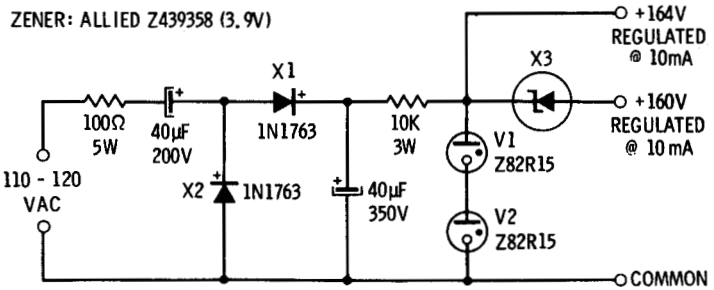


Fig. 7-2. Neon-regulated supply.

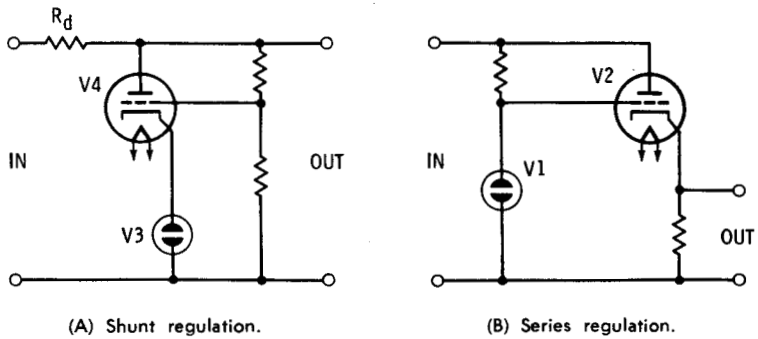


Fig. 7-3. Basic vacuum-tube regulators.

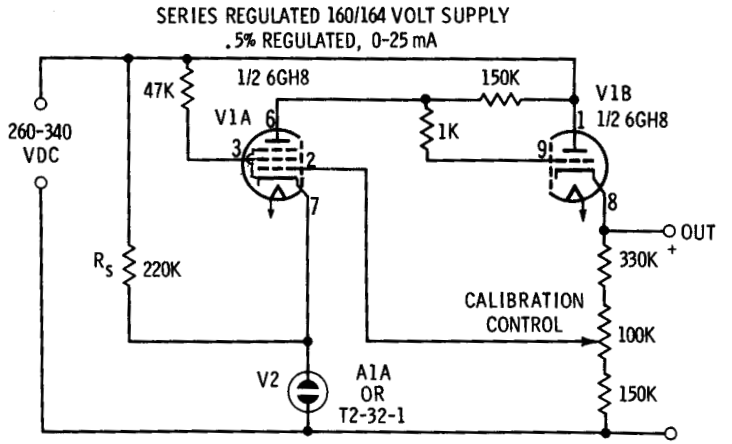


Fig. 7-4. Series-regulated supply.

ited by the ratings of V3 (15 mA max) and the value of R_d. In spite of this the series circuit is rarely used by itself because it is not as sensitive to voltage changes. The shunt circuit, however, has better regulating action and is used extensively to regulate high voltages at low currents. The maintaining voltage of the lamp, or lamps, plus the maximum rated plate voltage of the tube will determine the maximum voltage that can be regulated. A scheme similar to this is used to regulate the high-voltage supply of color television receivers.

Both types of regulators can be combined as shown in Fig. 7-4. Voltage changes in the load are sensed by the shunt pentode, which amplifies the error and drives the series-pass tri-

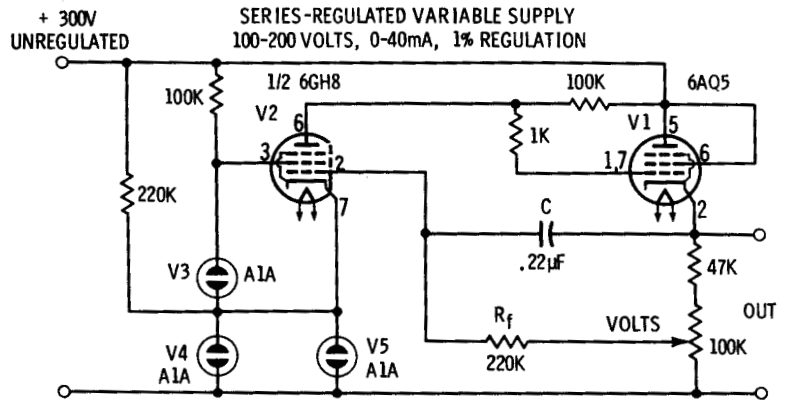


Fig. 7-5. Series-regulated variable supply.

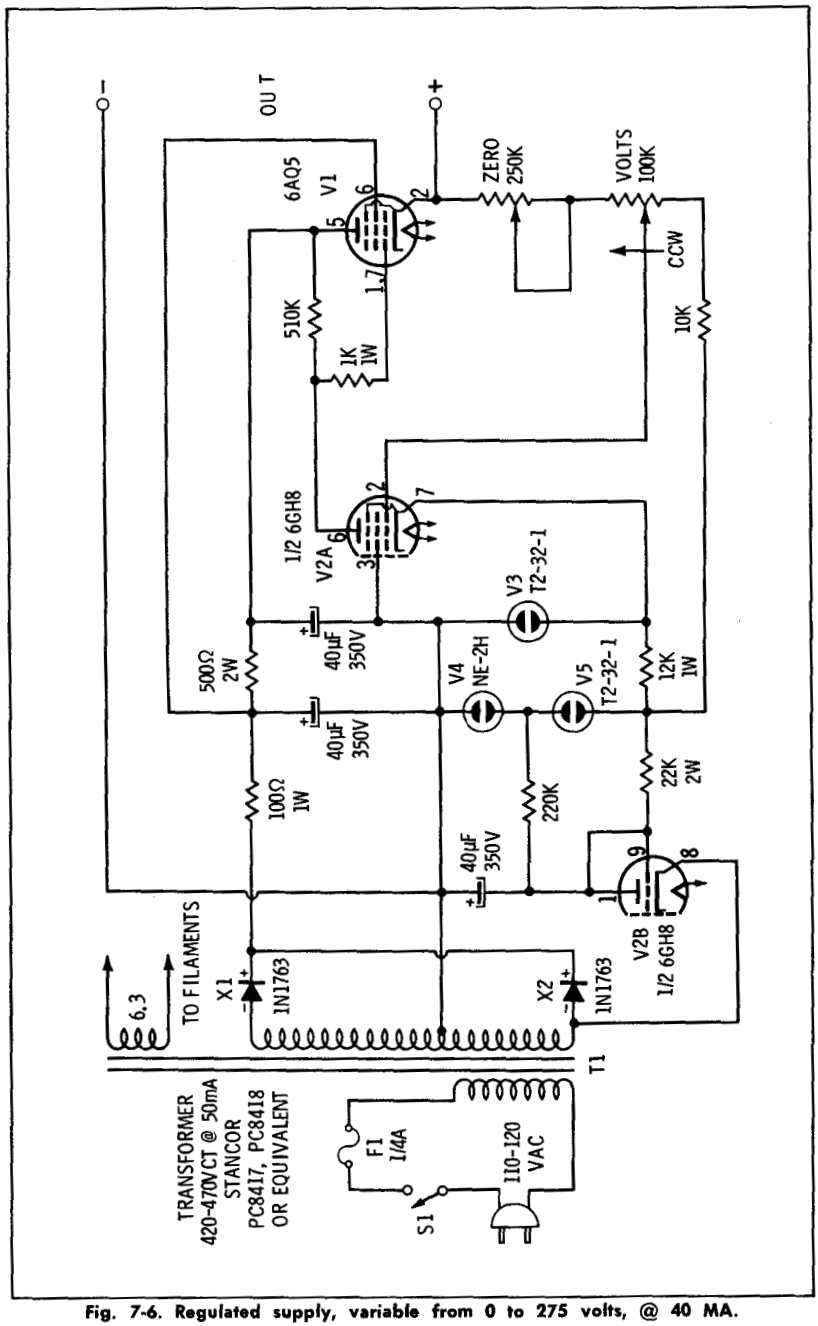


Fig. 7-6. Regulated supply, variable from 0 to 275 volts, @ 40 MA.

ode. Current to V2 is supplied through R_s, which improves regulation by making the voltage drop across V2 independent of the cathode current of the pentode.

Higher current and a wider voltage range are available from the circuit in Fig. 7-5. Screen-grid regulation has been added to the shunt tube, and ripple control is provided by R_f and C.

Fig. 7-6 is a complete low-cost power supply intended for the shop or for testing glow lamps. It uses a small transformer and two miniature tubes. One-half of the 6GH8 is connected as a diode and used to develop a rectified negative voltage for the cascaded neon lamps. V3 keeps the cathode of the shunt tube at −60 V or more so the output voltage can be adjusted all the way down to zero. V4 is ionized by the 220k resistor and can be brought out to the front panel as an indicator. T2-32-1 lamps were chosen for V3 and V5 because of their higher current capability but any standard-brightness indicator can be used that has low breakdown and maintaining voltages. The ZERO control is used to adjust the output to zero volts when the VOLTS control is in the extreme ccw position. If the lamps have not been pre-aged the output will drift slightly, so the power supply should be left on for at least 72 hours before this adjustment is made.

Fig. 7-7 is a set of regulation curves for the power supply shown in Fig. 7-6.

VOLTAGE CALIBRATORS

Miniature neon regulators can be particularly useful as a source of precision voltages. The calibrators shown in the illustrations offer a few of the possibilities, and were designed with economy as the prime consideration.

Fig. 7-8 is a simple dc calibrator that offers 1 percent accuracy when the potentiometer arm is in the extreme cw position (100V). A pointer knob on the shaft selects the desired voltage from a calibrated dial, which in this case is a transfer letter switch pattern. Ten of the twelve switch positions are used since this corresponds to the standard 294/300-degree potentiometer such as the Mallory M10MPK. As the pointer is moved in a ccw direction the accuracy is derated by the dial markings, the linearity of the control, and the impedance of the load, which now forms a voltage divider with the poten-

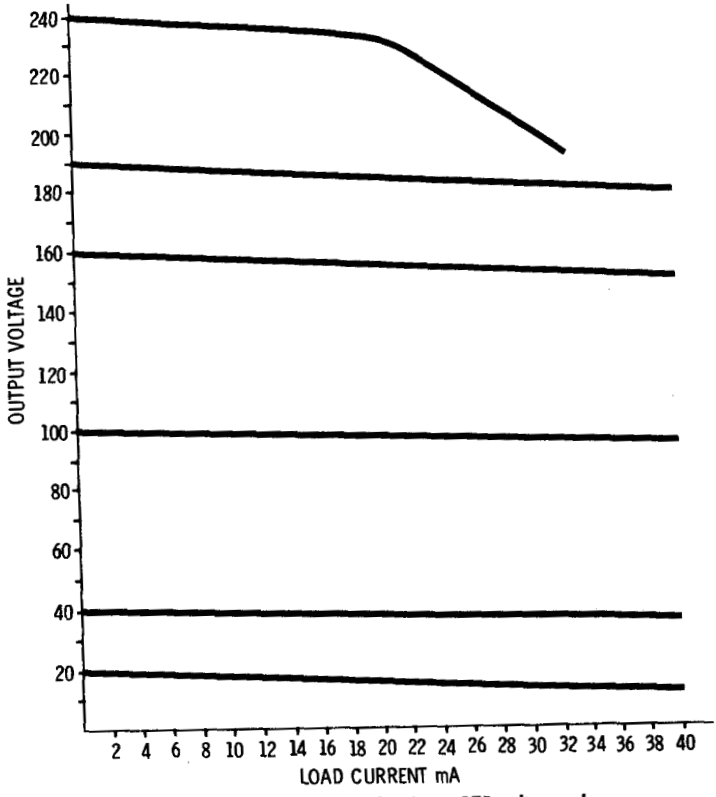


Fig. 7-7. Regulation curve for 0- to 275-volt supply.

tiometer. Diode X2 is included to null out the voltage drop caused by shunt-starting diode X1.

Higher accuracy is available from the instrument shown in Fig. 7-9. Linearity and dial-marking errors are eliminated by

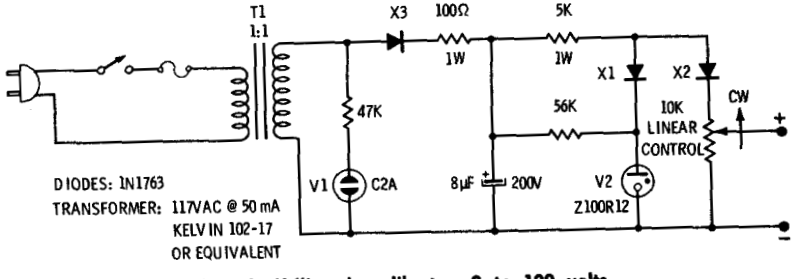


Fig. 7-8. Utility dc calibrator, 0 to 100 volts.

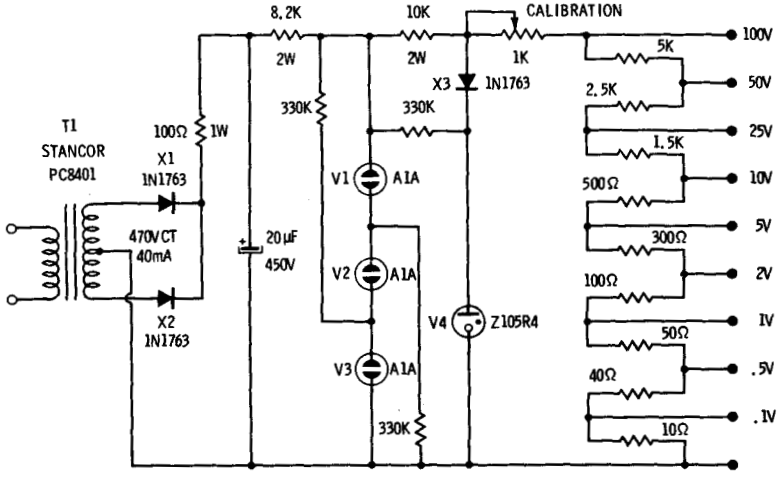


Fig. 7-9. High-precision, fixed-voltage calibrator.

using a fixed voltage divider, and since the 100 volts is adjusted precisely by the CAL control, the accuracy of this source is determined mainly by the tolerance of the resistors used in the divider and by the external loading. The cascaded section provides increased stability and it should be noted that while there is a current of 10 mA through the divider there is a current of only 2 mA through the A1A lamps.

Digital readout is the feature of the reference supply shown in Fig. 7-10. A turns-counting dial and a 10-turn potentiometer combine to give a precise source of continuously-variable voltages. The value of R was set at 50k since many high-voltage circuits can be made inoperative by a low impedance. The value of R can be increased to any desired value without further circuit changes, but if the instrument is to be used strictly for calibration purposes and a lower resistance is needed, then R_s will have to be decreased in value and the SET control readjusted. Actually the SET control would be unnecessary if pre-aged circuit component lamps with guaranteed voltage characteristics were used in place of the seven A1A neons. These lamps were used as a matter of convenience, but their wide range of voltage characteristics makes the 25k adjustment necessary. Initially the circuit should be interrupted at point A and a milliammeter inserted while the SET control is adjusted for a meter reading of 2 mA. The procedure is re-

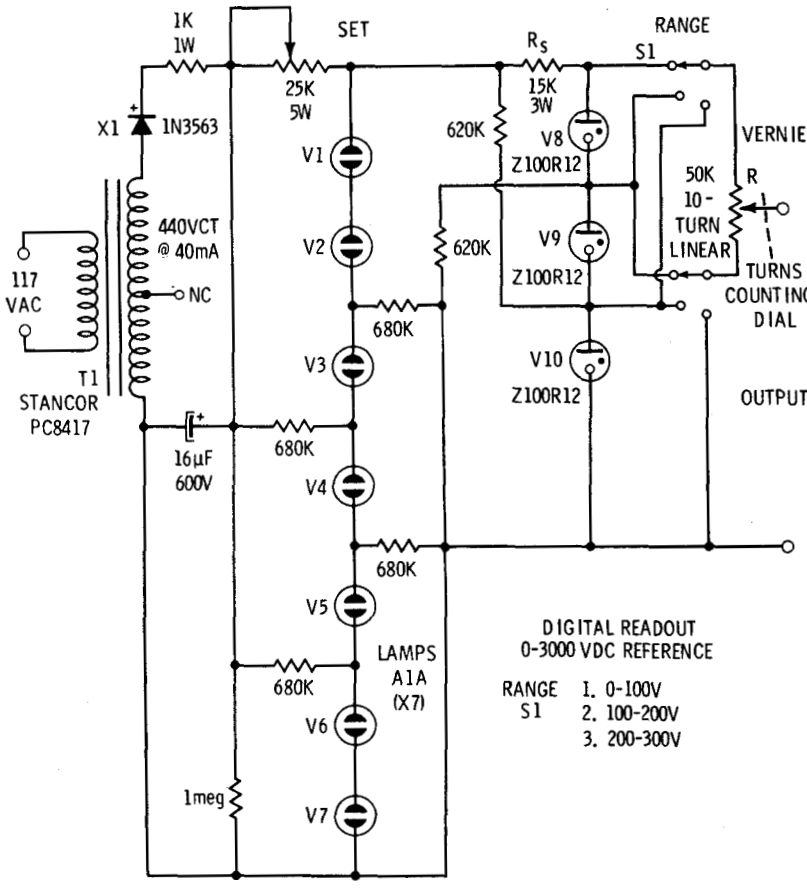


Fig. 7-10. 0- to 300-Vdc reference with digital readout.

peated after 72 hours of operation. BNC connectors are used in the output but binding posts or a combination of both may be more suitable. The BNC connectors must be insulated from the chassis by a fiber washer or similar device.

One interesting use for the digital calibrator is the precise measurement of peak-to-peak waveforms. If the waveform to be measured is applied to one vertical input of a dual-trace dc oscilloscope, and the calibrator output is applied to input number two, the calibrator can be adjusted to cause a base line to touch one peak of the waveform. The voltage reading is recorded from the digital dial and the calibrator is adjusted to

move the base line to the opposite peak of the waveform. The difference between the latter reading and the first reading is the peak-to-peak voltage of the waveform. If the oscilloscope has an algebraic addition circuit, it can be used with the calibrator to measure differences as small as 100 mV on a 250V pk-pk waveform.

Fig. 7-11 shows a high-stability ac calibrator with a vernier-dial readout. When the dial is attached to the potentiometer the control can be varied for only 180 degrees of the possible 300. This means that the shaft should be in the extreme ccw position and the vernier dial set at zero when the two components are secured to each other. The dial is then rotated to 10 and the CAL control is adjusted for a 10-volt pk-pk output.

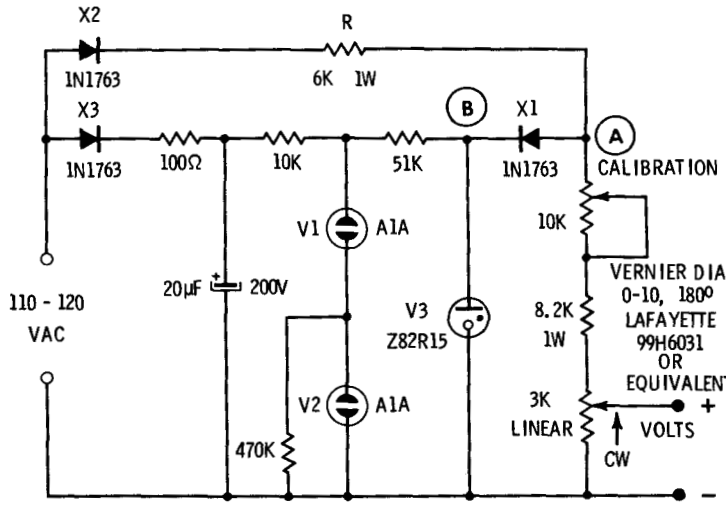


Fig. 7-11. Ac calibrator, 0- to 10-volt range with vernier readout.

The positive half of the ac sine wave is applied to point A through a diode and the 6k resistor. Normally this point could reach 160 volts, which is the peak value of one half of a line-voltage alternation, but voltage-divider action with the two potentiometers and the 8.2k resistor limits the maximum possible voltage at this point to 115 volts. Under the conditions shown in the illustration, point B is at 82 volts and diode X1 will conduct when point A exceeds this value. In effect, point A can never exceed 82 volts because of the clamping action of

diode X1. Point A then, has an 82-volt square wave that is divided down to a usable ten volts for the decade dial. An isolation transformer similar to the one shown in Fig. 7-8 should be used at the input.

The calibration circuit of Fig. 7-12 can be used to adjust the output of precision voltage sources such as the one shown in Fig. 7-9. R1 is inserted and the voltage to be calibrated is adjusted for a meter reading of zero. Any nulling device, bridge, or VTVM with a zero-center feature can be used in place of meter M1. R1 is found by the following formula:

$$R1 = 10{,}000(E - 2)$$

Where,

E is the desired voltage in volts.

The 0.3-percent accuracy is based on the use of a 0.1-percent tolerance multiplier.

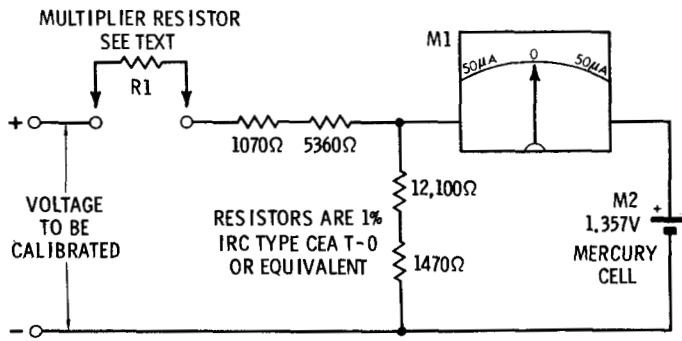


Fig. 7-12. Voltage calibration circuit with 3-percent accuracy.

TRANSIENT VOLTMETER

Neon-lamp voltmeters appear in many forms on the market, but their major use has been limited to handymen and hobbyists since the accuracy of these types is usually quite poor. Difficulty in stabilizing the breakdown voltage is perhaps the main reason, but there are many others. The circuit in Fig. 7-13 is included because it can perform a function that digital and D'Arsonval meters cannot. As the name implies, it can be used to measure transients that last for less than 100μs. This is particularly useful in circuits that combine solid-state com-

ponents with inductors, as, for example, a circuit using relays and diodes. If the voltmeter input is connected across the relay coil, the calibrated knob can be rotated until the de-energization of the relay causes the A083 to light. Calibration marks on the knob skirt will give the approximate value of the transient generated by the relay and the engineer can now determine the voltage ratings for the diodes. Initially the VOLTS control is put in the extreme ccw position and the 0-10 knob-skirt markings are positioned in such a manner as to place the numeral 1 opposite the chassis indexing mark or dot. 1100 volts will read off-scale.

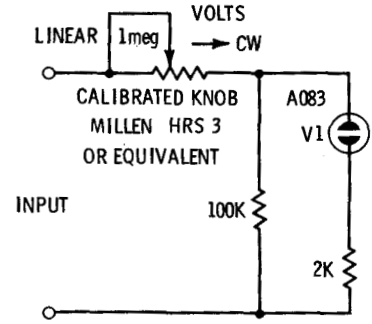


Fig. 7-13. Transient voltmeter, range 100 to 1100 volts.

ELECTRICIAN'S FRIEND

A simple and useful service tool is shown in Fig. 7-14. It can be connected to any power main or junction box and will tell the user at a glance what the line voltage is and whether it is ac or dc. The ac lamp will light only on ac and the dc lamp will light only on dc. The LO lamp will come on at 70 Vdc or 50 Vac and the 110 and 220 lamps will come on at their rated voltages,

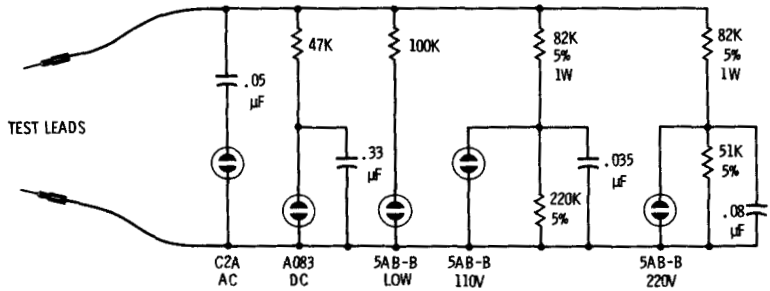


Fig. 7-14. Circuit for the Electrician's Friend.

ac *or* dc. Actually the 220 lamp will come on at 210 volts since this is usually considered acceptable.

HIGH-ENERGY DETECTOR

Fig. 7-15 shows a homemade version of several commercially available high-voltage probes. High-voltage or high-energy rf fields will ionize the NE51 directly and cause the gas to glow, making it useful for many go/no-go applications. It can be brought close to the output circuit of a transmitter and the tank circuit can then be adjusted for maximum brightness of the lamp. When the probe is held near a television flyback transformer it will give the repairman a quick indication of the presence of high voltage, and positioning the lamp near a spark plug wire will indicate whether the plug is firing or not.

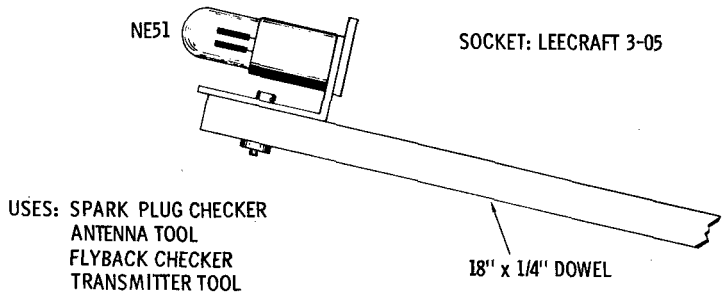


Fig. 7-15. High-energy detector.

A-M SIGNAL GENERATOR

An af relaxation oscillator is used to shock excite the tank circuit in Fig. 7-16. Any a-m radio knob that has frequency

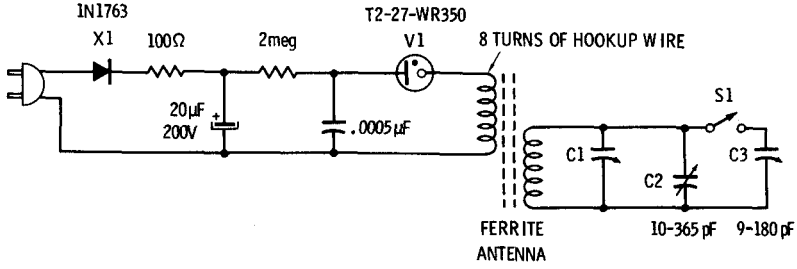


Fig. 7-16. Junk box a-m signal generator, range 455 to 1650 kHz.

markings on it can be used as the dial for C2. C1 is a trimmer and C3 can be switched in for 455 kHz. The radio can be several feet from the generator and the output will still be ample for alignment purposes. Several ferrite antenna types were tried and all worked equally well. The frequency of the audio oscillator should be over 1 kHz for reliable operation. With S1 closed, and C2 set for maximum capacity, C3 is adjusted from minimum capacity until a tone is heard in a radio that is correctly aligned. C3 is now set for 455 kHz and the output should easily penetrate the input stages of 5-tube radios and most transistor types, so no direct connection is necessary in aligning the i-f's.

8

Reference Section

LIGHT OUTPUT

Standard-brightness lamps radiate energy in the 5200-5400, 5700-7500, and 8200-8800 Angstrom bands with an average overall efficiency of .06 lumen per milliampere.

High-brightness lamps operate in the 5700-7500 and 8200-8800 Angstrom bands with an overall efficiency of .15 lumen per milliampere.

Argon lamps radiate in the 300-4700 (near ultra-violet) and 5500-9500 Angstrom bands.

Helium-argon lamps have three minor radiation bands between 3400-6400Angstroms and a major energy output between 7000-9000 Angstroms.

SHUNT CAPACITANCE AND INTERNAL RESISTANCE

The shunt capacitance for an extinguished glow lamp varies from 0.5 to 1.5 pF, depending on the size of the electrodes and the pressure of the gas.

Dynamic internal resistance figures vary widely and depend on four main parameters: the type of gas, the gas pressure, the electrode material, and the operating current. Of these, the operating current is of the most concern. A lamp operating at under 1 mA will usually have a dynamic resistance of over 4000 ohms, whereas a lamp operated at 10 mA may have a resistance of 500 ohms. As a general rule, lamps

of the same designation will have internal resistances that are within 1 percent of each other.

Internal resistance figures are not included on specification sheets because in most cases the values are insignificant. The A1A, for instance, has a characteristic resistance of 5500 ohms at design current, and when it is operated at line voltages, it uses a 220k series resistor. Since 5.5k is less than 3 percent of 220k, and the series resistor is usually a 20-percent type, the internal resistance can be ignored.

It is for this reason that the formulas in the preceding chapters do not include internal resistance. If, however, the supply voltages are close to the maintaining voltages, then the internal resistance can represent an important part of the whole. In this case, the internal resistance should be subtracted from the calculated value to arrive at the correct value of series resistance.

DRI-FILM COATING AND LEAKAGE

All neon lamps have a leakage resistance in the 1000-megohm region under ideal conditions, but when the relative humidity increases and moisture condenses on the lamp, an external conductive path is provided.

A commercial coating that is furnished on some lamps and referred to as *Dri-film* by GE causes the moisture to collect in little puddles in a manner similar to rain puddles on a freshly waxed car. Since these small puddles do not touch each other, the resistance remains high.

The recommended method for measuring leakage resistance is to apply 40 volts to a lamp in series with a microammeter. The resulting current will indicate the leakage under dynamic conditions. A reading of 0.4 microampere would indicate a leakage resistance of 100 megohms, which is a standard figure in the industry.

AGING PROCEDURES

Standard-brightness lamps—Twenty-four hours at 2 times the design current, followed by 24 hours under typical circuit operating conditions.

High-brightness lamps—Fifteen minutes at 15-17 mA, followed by 24 hours under typical operating conditions.

Large-differential (high-pressure types)—Four hours at 3 times the design current, followed by 24 hours under typical circuit conditions.

High-current types—Twenty-four hours at 15 mA, followed by 24 hours under typical operating conditions.

The foregoing procedures have found wide acceptance by the electronic industry and are recommended in most cases. They are designed to stabilize the lamp in the shortest possible time with a minimum amount of sputtering (darkening). Actually most lamps will stabilize after 100 hours of operation at their design current, but since time is usually a factor, accelerated aging may be used.

If regulation as well as improved stabilization is required, then higher aging currents for longer periods of time are recommended. The sputtering can be disregarded since appearance and light output are usually not important in circuit component types. High-current aging also produces higher breakdown and maintaining voltages, which may exclude it from some applications.

No formula for aging has yet been worked out to include all the variables, such as gas type, gas pressure, electrode material, etc., so the user as well as the manufacturer must sometimes experiment to produce a desired result.

The electrode size and internal gas pressure will determine the limits of the experimental aging current. High-pressure gas and 12-mm electrodes indicate higher possible currents. Some commercial types are aged at currents over 30 mA for extended periods of time, but controlled conditions such as forced air cooling are required.

The higher-pressure tubes are usually easy to identify as they have a higher breakdown voltage, and the corona has a tendency to concentrate in one spot. Low-pressure tubes, on the other hand, produce low breakdown voltages and a "soft" corona that covers the entire electrode.

In looking over the specification chart for T-2 neons, it can be seen that precise maintaining voltages can be had for over 30,000 hours, but breakdown voltages are more difficult to stabilize, especially with pure neon (high brightness), so a maximum figure is usually given. A guaranteed breakdown voltage ±1 volt would have to include the ambient lighting conditions to be valid. A tube of this type would almost cer-

tainly be a low-pressure neon-argon mixture with a radioactive additive.

AGING EQUIPMENT

It has been found experimentally that lamps aged on pulsating dc exhibit superior qualities to those stabilized on pure or filtered dc. One explanation that has been offered is that while both methods use the same average current to stabilize the gas, the pulsating dc has a higher peak current, which aids in the cathode "cleaning up" process.

The circuit in Fig. 8-1 is a general-purpose device that will satisfy most aging requirements. The 220 Vac is needed for

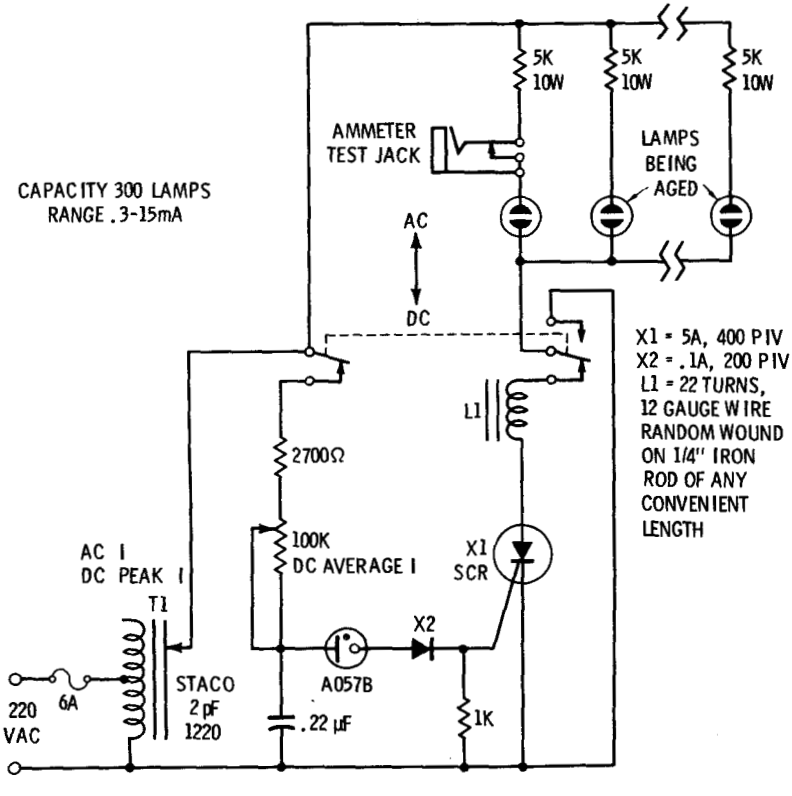


Fig. 8-1. Universal ac-dc aging circuit.

the higher breakdown types, and the variable autotransformer may be used to adjust the peak dc current.

For lamps that are aged at currents greater than 4 mA, it is recommended that at the end of the aging cycle the current be reduced over a period of several minutes. This prevents a rapid temperature change from making the glass brittle.

A period of 24 hours in the nonconducting state is then advised before the aged lamps are tested to their electrical specifications. This is particularly important for breakdown voltage tests which may produce as much as a 5-volt rise in 24 hours after accelerated aging.

NEON-LAMP SPECIFICATION CHART AND NUMBERING SYSTEMS

The following chart represents nearly all of the neon lamps available in the United States as stock items. Many other types have been manufactured to meet individual customer needs and are usually assigned a number that is preceded by the letter "A." This "Application" numbering system is necessary when it is realized that any change in the manufacturing process will indicate a change in the alpha-numeric designation. If, for instance, an equipment manufacturer wants a 5AG lamp with guaranteed ionization time specifications, it will be assigned an "A" number, even though it originally was a 5AG. Sometimes these special lamps become popular enough to be made available as stock items, as, for example, the A057B, A016, etc.

The oldest and usually most familiar system of classifying glow lamps is the "NE" method and for this reason they are listed in the left hand column.

The shortcomings of the "NE" system were noted by the industry and as a result the American Standards Association (ASA) offered a new system for lamp identification that included clearly defined standards. The ASA has been renamed USAS (United States American Standard) and this designation is the one recommended for current use. The system applies only to neons that are primarily used as indicators. There is no USAS numbering system for circuit component types.

General Electric identifies circuit component lamps with a set of alpha-numeric characters that is similar to and com-

patible with the USAS method. The GE system always begins with a number and is followed by two or three letters.

Tech-Neon and Signalite use an industrial system for high volume types that is designed to minimize confusion by coding the characteristics into the identification number. A T2-27-2T, for instance, will indicate to the user that this is a T2 bulb, 27/32″ long, filled with standard brightness gas, and has 2″ tinned wire leads.

A quick glance at the chart will show that in many cases the difference between one lamp and another is slight, such as the type of tip, length of bulb, length of lead, extinguishing volt-test, etc. For many types, this simplifies replacement and substitution problems.

USING THE SPECIFICATION CHART

The listings are divided into 3 groups: T2 miniature neon lamps, T4½ to S14 gas lamps, and T2 miniature voltage regulators. The T4½ to S14 group is included for reference, and, with the exception of the NE51 types, their circuit component use is limited.

The "T" in T2 describes the shape of the glass, tubular, and the "2" refers to the approximate diameter in eighths of an inch. For all new types, this represents a maximum diameter of .250 in., but for some older types it is .275 in.

The first three columns provide a cross-reference and show the lamp designation under any of the systems discussed. Thus an A7A, T2-24-1, and NE2B are all the same lamp.

B'kdwn Volts is self-explanatory and footnotes are included for special conditions.

Maint Volts figures are based on the listed design current.

Exting Volts shows the guaranteed extinguishing voltage and indicates that each lamp is tested to this specification.

Des I mA lists the design current which is the basis of the life and maintaining voltage figures. The design current is not the maximum operating current.

Life Avg Hours figures for standard brightness indicators are based on a 50-percent decrease in light output. The life of high-brightness indicators is based on the point at which standard line voltages (115 Vac) will fail to ionize the lamp. Circuit component figures are explained by footnotes.

Typ R_s Ohms is the value of resistance, ±20 percent, that would usually be used in series with the indicator on a 115 Vac line.

Pre-Aged indicates whether or not the lamp has been factory aged, and footnotes explain how the anode is identified.

Bulb Length Max In. is self-explanatory.

Base describes the method used to terminate the lamp.

Footnotes indicate special conditions and are listed at the end of the chart.

The T4½ to S14 chart is essentially the same as the T2 chart and uses the same footnotes. There are a few additions.

Bulb Type is indicated by the same system as the T2. G is globe-shaped and S is straight-sided. The numbers show the maximum diameter in eighths of an inch.

MOL In. is the maximum overall length in inches, including the base.

T2 Miniature Neon Lamps

Designation			DC Voltage Ratings						Des.	NOTES	Life	NOTES	Typ.	Pre-Aged	NOTES	Bulb	NOTES	Base	Notes
NE	USAS	Other	B'kdown Volts	NOTE	Maint. Volts	NOTE	Exting. Volts	NOTE	I mA.		Avg. Hours		R_x Ohms			Length Max. In.			
NE2	A1A		70 Avg.	13	59 Avg.	13	– – – – – –		.3		6,000	2	– –	NO		$1\frac{1}{16}$		1" Wire	15
NE2A	A2A		70 Avg.	13	59 Avg.	13	– – – – – –		.3		2,500	2	– –	NO		$\frac{27}{32}$		2" Wire	
NE2A1	A4A		90 Max.			27	– – – – – –		.3		25,000	7	220K	NO		$\frac{27}{32}$		1" Wire	
NE2AS			60-90		58 Avg.	13	50 Min.	1	.3		2,500	2	– –	NO		$\frac{27}{32}$		2" Wire Tinned	3
NE2AT	A2A-T		90 Max.		59 Avg.	13	– – – – – –		.3		25,000	7	220K	NO		$\frac{27}{32}$		2" Wire Tinned	
NE2B	A7A	T2-24-1	90 Max.			27	– – – – – –		.6		25,000	7	100K	NO		$\frac{24}{32}$		1" Wire	
NE2B1	A8A	T2-24-2	90 Max.			27	– – – – – –		.6		25,000	7	100K	NO		$\frac{24}{32}$		2" Wire	
NE2D	C7A		90 Max.			27	– – – – – –		.7		25,000	7	100K	NO			25	S.C. Mid. Flange	4
NE2E	A9A		90 Max.			27	– – – – – –		.7		25,000	7	100K	NO		$\frac{24}{32}$		2" Wire	4
NE2E1	A9A-C		90 Max.			27	– – – – – –		.7		25,000	7	100K	NO		$\frac{24}{32}$		1" Wire	4
NE2E1T	A9A-CT		90 Max.			27	– – – – – –		.7		25,000	7	100K	NO		$\frac{24}{32}$		1" Wire Tinned	4
NE2E2	A9A-D		90 Max.			27	– – – – – –		.7		25,000	7	100K	NO		$\frac{24}{32}$		$\frac{7}{16}$" Wire	4
NE2E3	A9A-E		90 Max.			27	– – – – – –		.7		25,000	7	100K	NO		$\frac{24}{32}$		$\frac{9}{32}$-$\frac{1}{2}$" Wire	4
NE2E4	A9A-B		90 Max.			27	– – – – – –		.7		25,000	7	100K	NO		$\frac{24}{32}$		2" Wire	4, 26
NE2E5	A9A-F		90 Max.			27	– – – – – –		.7		25,000	7	100K	NO		$\frac{24}{32}$		3" Wire	4
NE2ET	A9A-T		90 Max.			27	– – – – – –		.7		25,000	7	100K	NO		$\frac{24}{32}$		2" Wire Tinned	4
NE2F	A3A	T2-27-2	90 Max.			27	– – – – – –		.6		25,000	7	100K	NO		$\frac{27}{32}$		2" Wire	
NE2H	C2A		135 Max.			24	– – – – – –		1.9		25,000	7	30K	NO		$\frac{24}{32}$		2" Wire	8, 4, 6
NE2H1	C2A-C		135 Max.			24	– – – – – –		1.9		25,000	7	30K	NO		$\frac{24}{32}$		1" Wire	8, 4, 6
NE2H2	C2A-D		135 Max.			24	– – – – – –		1.9		25,000	7	30K	NO		$\frac{24}{32}$		$\frac{7}{16}$" Wire	8, 4, 6
NE2H3	C2A-E		135 Max.			24	– – – – – –		1.9		25,000	7	30K	NO		$\frac{24}{32}$		$\frac{3}{8}$" Wire	8, 4, 6
NE2H4	C2A-F		135 Max.			24	– – – – – –		1.9		25,000	7	30K	NO		$\frac{24}{32}$		$3\frac{1}{4}$-$2\frac{3}{8}$" Wire	8, 4, 6
NE2H5	C2A-G		135 Max.			24	– – – – – –		1.9		25,000	7	30K	NO		$\frac{24}{32}$		$5\frac{7}{16}$" Wire	8, 4, 6
NE2H6	C2A-H		135 Max.			24	– – – – – –		1.9		25,000	7	30K	NO		$\frac{24}{32}$		$\frac{1}{2}$" Wire	8, 4, 6
NE2H7	C2A-J		135 Max.			24	– – – – – –		1.9		25,000	7	30K	NO		$\frac{24}{32}$		$1\frac{3}{16}$" Wire	8, 4, 6
NE2H8	C2A-K		135 Max.			24	– – – – – –		1.9		25,000	7	30K	NO		$\frac{24}{32}$		$1\frac{1}{2}$-2" Wire	8, 4, 6
NE2HT	C2A-T		135 Max.			24	– – – – – –		1.9		25,000	7	30K	NO		$\frac{24}{32}$		2" Wire Tinned	8, 4, 6
NE2J	C9A		135 Max.			24	– – – – – –		1.9		25,000	7	30K	NO			25	S.C. Mid. Flange	8, 4, 6

NE2L			65-85		>50	13	– – – – – –		.3		6,000	2	– –	NO		24/32		2" Wire	4, 5, 6
NE2M	K2A		90 Max.			27	– – – – – –		.5		25,000	7	150K	NO		23/32		1" Wire	23
NE2MT	K2A-T		90 Max.			27	– – – – – –		.5		25,000	7	150K	NO		23/32		1" Wire Tinned	23
NE2P	K3A		135 Max.			24	– – – – – –		1.9		25,000	7	30K	NO		23/32		1" Wire	8, 23
NE2S			60- 90		44- 74		50 Min.	1	.3		6,000	2	250K	NO		1 1/16		1" Wire Tinned	3, 5, 6
NE2U	A3C		75-135		60-105		– – – – – –		1.9		25,000	7	30K	NO		24/32		2" Wire	4, 6, 8, 28
NE2UT	A3C-T		75-135		60-105		– – – – – –		1.9		25,000	7	30K	NO		24/32		2" Wire Tinned	4, 6, 8, 28
NE2V	A2B		60- 90		46- 78		– – – – – –		.7		25,000	7	100K	NO		24/32		2" Wire	4, 6
NE2V1	A2B-C		60- 90		46- 78		– – – – – –		.7		25,000	7	100K	NO		24/32		1" Wire	4, 6
NE2VT	A2B-T		60- 90		46- 78		– – – – – –		.7		25,000	7	100K	NO		24/32		2" Wire Tinned	4, 6
NE2X			90 Max.			27	– – – – – –		.6		25,000	7	100K	NO		1		1" Wire	
NE2Y	A4B		90 Max.			27	– – – – – –		.7		25,000	7	100K	NO			25	S.C. Mid. Flange	4, 6
NE3		8AA	55- 90		>55	13	50 Min.	1	.3		15,000	9	– –	NO			10	#1 Tel. Slide	11, 15, 22
NE4		8AB	60- 90		44- 74		– – – – – –		.3		6,000	2	– –	NO			10	#1 Tel. Slide	15, 22
NE5		8AC	120-150		60- 80		– – – – – –		.5		3,000	12	– –	NO			10	#1 Tel. Slide	6, 15, 22
NE23		5AB	60- 90		59 Avg.	13	– – – – – –		.3		6,000	2	– –	NO		1 1/16		1" Wire	6
NE2T	A1A-T		90 Max.			27	– – – – – –		.5		*25,000*	*7*	*150K*	*NO*		*1 1/16*		*1" Wire Tinned*	*15*
NE68		5AC	60- 90		52- 65		50 Min.	1	.3		2,000	2	– –	YES	14	1 1/16		1" Wire Tinned	6, 5, 15
NE68A			60- 90	16	52- 65		50 Min.	1	.1-.3		2,000	2	– –	YES	17	1 1/16		1" Wire Tinned	6, 5, 15
NE75			60- 90		>55	13	50 Min.	1	.4		10,000	9	– –	NO		24/32		1" Wire	4
NE76		5AG-A	68- 76		50- 60		50 Min.	1	.4		2,000	18	– –	YES	19	1 1/16		1"-1 1/2" Wire Tin.	6, 5, 15
NE80			60- 80		50- 58		50 Min.	1	.1		2,000	9	– –	YES	20	1 1/16		1" Wire Tinned	6, 5, 15
NE81		5AG	64- 80		50- 60		50 Min.	1	.3		2,000	18	– –	YES	21	1 1/16		1" Wire Tinned	6, 5, 15
NE82			63- 76	13	50- 60		– – – – – –		1.5		2,000	35	– –	YES		1 1/16		1" Wire	
NE83		5AH	60-100		65 Avg.	13	– – – – – –		10.	34	500	2	– –	*NO*		1 1/16		*1" Wire Tinned*	4, 6, 5
NE84	K1A5		135 Max.			24	– – – – – –		1.9		25,000	7	30K	NO			29	#5 Tel. Slide	8, 4, 6, 22
NE86		5AJ	55- 90		55 Avg.	13	– – – – – –		1.5		2,000	2	– –	NO		1 1/16		1" Wire Tinned	4, 6, 15
NE96		4AB	120-150		60- 80		– – – – – –		.5		3,000	12	– –	*NO*		27/32		1" Wire	6, 15
NE97		4AC	110-140		60- 80		– – – – – –		.5		3,000	12	– –	NO		27/32		1" Wire	6, 15
NE98		3AD	65- 80		>50		50 Min.	1	.3		6,000	2	– –	NO		24/32		2" Wire Tinned	4, 6, 5
NE99		2AA	65- 80		48- 58		– – – – – –		.3		7,500	2	– –	NO		1/2		1" Wire	4, 6
AR9	K4A		115 Max.		– – –		– – – – – –		.3		50	30	200K	NO		1 1/16		1" Wire	32

T2 Miniature Neon Lamps

Designation			DC Voltage Ratings						Des. I mA.	NOTES	Life Avg. Hours	NOTES	Typ. R, Ohms	Pre-Aged	NOTES	Bulb Length Max. In.	NOTES	Base	Notes
NE	USAS	Other	B'kdown Volts	NOTE	Maint. Volts	NOTE	Exting. Volts	NOTE											
HA6	K5A		125 Max.		— — —		— — — — —		.3		1,000	31	220K	NO		$1\frac{1}{16}$		1" Wire	33
	A1A-A		90 Max.			27	— — — — —		.5		25,000	7	150K	NO		$1\frac{1}{16}$		$2\frac{9}{16}$" Wire	
	A1B		90 Max.			27	— — — — —		.3		25,000	7	220K	NO		$\frac{1}{2}$		1" Wire	4
	A1C		135 Max.			24	— — — — —		1.2		25,000	7	47K	NO		$\frac{1}{2}$		1" Wire	4, 8, 6
	A1C-A		135 Max.			24	— — — — —		1.2		25,000	7	47K	NO		$\frac{1}{2}$		2" Wire	4, 8, 6
	A1C-T		135 Max.			24	— — — — —		1.2		25,000	7	47K	NO		$\frac{1}{2}$		1" Wire Tinned	4, 8, 6
	A1D		90 Max.			27	— — — — —		.3		25,000	7	220K	NO		$\frac{1}{2}$		1" Wire	4, 6
	A1D-T		90 Max.			27	— — — — —		.3		25,000	7	220K	NO		$\frac{1}{2}$		1" Wire Tinned	4, 6
	A1G		90 Max.			27	— — — — —		.3		25,000	7	220K	NO			36	S.C. Mid Flange	4
	A1H		135 Max.			24	— — — — —		1.2		25,000	7	47K	NO			36	S.C. Mid Flange	4, 8, 6
	A1K		135 Max.			24	— — — — —		1.2		25,000	7	47K	NO		$\frac{1}{2}$		1" Wire	4, 8, 6
	A2B-D		90 Max.			27	— — — — —		.7		25,000	7	100K	NO		$\frac{24}{32}$		$\frac{5}{8}$-$1\frac{1}{4}$" Wire	4, 6
	A6A	T2-32-1	90 Max.			27	— — — — —		1.		25,000	7	— —	NO		$1\frac{1}{16}$		1" Wire	46
	A9A-G		90 Max.			27	— — — — —		.7		25,000	7	100K	NO		$\frac{24}{32}$		2" Wire	4, 5
	C2A-B		135 Max.			24	— — — — —		1.9		25,000	7	30K	NO		$\frac{24}{32}$		2" Wire	4, 8, 6
	C2A-CT		135 Max.			24	— — — — —		1.9		25,000	7	30K	NO		$\frac{24}{32}$		1" Wire Tinned	4, 8, 6
	C2B		135 Max.			24	— — — — —		1.9		25,000	7	30K	NO			37	Mid. Grooved	4, 8, 6
	C3A	LT2-24-1	135 Max.			24	— — — — —		1.5		25,000	7	— —	NO		$\frac{24}{32}$		1" Wire	8
	C4A	LT2-27-1	135 Max.			24	— — — — —		1.5		25,000	7	— —	NO		$\frac{27}{32}$		1" Wire	8
	C5A	LT2-27-2	135 Max.			24	— — — — —		1.5		25,000	7	— —	NO		$\frac{27}{32}$		2" Wire	8
	C6A	LT2-32-2	135 Max.			24	— — — — —		1.5		25,000	7	— —	NO		$1\frac{1}{16}$		2" Wire	8
	D2A		135 Max.			24	— — — — —		2.6		25,000	7	22K	NO		$\frac{15}{16}$		1" Wire	4, 8, 6, 34
	K1B1		135 Max.			24	— — — — —		1.2		25,000	7	47K	NO			10	#1 Tel. Slide	8, 6, 22, 23
	K1C5		90 Max.			27	— — — — —		.7		25,000	7	100K	NO			29	#5 Tel. Slide	4, 22
	K1D5		135 Max.			24	— — — — —		1.9		25,000	7	30K	NO			38	#5 Tel. Slide	8, 6, 22, 23
	K2A-D		90 Max.			27	— — — — —		.5		25,000	7	150K	NO		$\frac{23}{32}$		$2\frac{1}{2}$" Wire	23
	K3A-A		135 Max.			24	— — — — —		1.9		25,000	7	30K	NO		$\frac{23}{32}$		1" Wire	8, 23, 6

	K3A-T		135 Max.			24	– – – – – –		1.9	25,000	7	30K	NO		23/32		1" Wire Tinned	8, 23, 6
		3AD-A	65- 80		Avg.>50		50 Min.	1	.3	6,000	2	– –	NO		24/32		4" Wire	4, 5, 6
		3AD-B	65- 80		Avg.>50		50 Min.	1	.3	6,000	2	– –	NO		24/32		3" Wire	4, 5, 6
		3AF	60- 75		– – –		– – – – – –		.75	– – –		– –	NO		24/32		1" Wire	4, 6, 13, 40
		3AG	60- 90		Avg.>58		– – – – – –		.4	2,000	2	– –	NO		24/32		2" Wire Tinned	4, 6
		3AG-A	60- 80		50- 65		50 Min.	1	.4	6,000	2	– –	YES	41	24/32		1 3/4-2" Wire Tin.	4, 6, 5
		3AG-B	65- 73		52- 62		50 Min.	1	.4	2,000	2	– –	YES	19	24/32		1 3/4-2" Wire Tin.	4, 6, 5
		3AG-C	68- 76		52- 62		50 Min.	1	.4	2,000	2	– –	YES	20	24/32		1 3/4-2" Wire Tin.	4, 6, 5
		3AG-D	60- 90		Avg.>58		– – – – – –		.4	2,000	2	– –	NO		24/32		3" Wire	4, 6
		3AG-E	65- 73			39	50 Min.	1	.4	2,000	2	– –	YES	17	24/32		1 3/4-2" Wire Tin.	4, 6, 42
		3AH	75-135		70 Avg.	13	– – – – – –		2.	2,000	12	– –	NO		24/32		2" Wire	4, 5, 6
		3AJ	60-100		Avg.>59		– – – – – –		5.	500	2	– –	NO		24/32		1" Wire Tinned	4, 5, 6
		3AJ-A	60- 80		52- 72		– – – – – –		5.	500	2	– –	YES	41	24/32		1" Wire Tinned	4, 5, 6
		3AJ-B	75-100		55- 75		– – – – – –		5.	500	2	– –	YES	21	24/32		1" Wire Tinned	4, 5, 6
		5AB-A	60- 80		50- 65		50 Min.	1	.3	6,000	2	– –	YES	19	1 1/16		1 7/8" Wire	6, 5
		5AB-B	62- 72		50- 60		50 Min.	1	.3	6,000	2	– –	YES	41	1 1/16		1 7/8" Wire	6, 5
		5AB-C	68- 78		55- 65		50 Min.	1	.3	6,000	2	– –	YES	21	1 1/16		1 7/8" Wire	6, 5
		5AB-D	60- 90	43	59 Avg.	13	– – – – – –		.3	6,000	2	– –	NO		1 1/16		2" Wire	6
		5AB-E	60- 90	43	59 Avg.	13	– – – – – –		.3	6,000	2	– –	NO		1 1/16		3" Wire	6
		5AB-F	60- 90	43	59 Avg.	13	– – – – – –		.3	6,000	2	– –	NO		1 1/16		2" Wire Tinned	6
		5AB-T	60- 90	43	59 Avg.	13	– – – – – –		.3	6,000	2	– –	NO		1 1/16		1" Wire Tinned	6
		5AH-A	60- 85		52- 67		– – – – – –		10.	500	2	– –	YES	41	15/16		1" Wire Tinned	4, 5, 6, 34
		5AH-B	75- 85		57- 68		– – – – – –		10.	500	2	– –	YES	19	15/16		1" Wire Tinned	4, 5, 6, 34
		5AH-C	75-100		52- 67		– – – – – –		10.	500	2	– –	YES	21	15/16		1" Wire Tinned	4, 5, 6, 34
		5AH-D	60- 85	44	50- 70		– – – – – –		3.	5,000	2	– –	YES	20	15/16		1-13/16" Wire Tin.	4, 5, 6, 34
		5AJ-A	55- 75		45- 65		– – – – – –		1.5	2,000	2	– –	YES	41	15/16		1" Wire Tinned	4, 5, 6
		5AJ-B	70- 90		55- 75		– – – – – –		1.5	2,000	2	– –	YES	21	15/16		1" Wire Tinned	4, 5, 6
		5AJ-C	55- 90		Avg.>57	13	– – – – – –		1.5	2,000	2	– –	NO		15/16		3" Wire	4, 5, 6
		8AE	60-100		Avg. 61	13	– – – – – –		10.	500	2	– –	NO			10	#1 Tel. Slide	4, 6, 22, 34
		T2-27-1	90 Max.			27	– – – – – –		.7	25,000	7	– –	NO		27/32		1" Wire	
		T2-27-1T	90 Max.			27	– – – – – –		.7	25,000	7	– –	NO		27/32		1" Wire Tinned	
		T2R-27-1	90 Max.			27	– – – – – –		– –	– – –		– –	NO		27/32		1" Wire + Res.	45

T2 Miniature Neon Lamps

Designation			DC Voltage Ratings						Des. I mA.	NOTES	Life Avg. Hours	NOTES	Typ. R_x Ohms	Pre-Aged	NOTES	Bulb Length Max. In.	NOTES	Base	Notes
NE	USAS	Other	B'kdown Volts	NOTE	Maint. Volts	NOTE	Exting. Volts	NOTE											
		LT2-32-1	135 Max.			24	– – – – – –		2.6		25,000	7	– –	NO		$1\frac{1}{16}$		1" Wire	8, 46, 47
		LT2-27-1T	135 Max.			24	– – – – – –		2.6		25,000	7	– –	NO		$\frac{27}{32}$		1" Wire Tinned	8
		LT2R-27-1	135 Max.			24	– – – – – –		– –		– – –		– –	NO		$\frac{27}{32}$		1" Wire + Res.	8, 45
		RT2-27-1	66- 83	48	52- 59		50 Min.	49	.5		10,000	9	– –	YES	17	$\frac{27}{32}$		1" Wire	6
		RT2-32-1A	70- 90	48	50- 65		50 Min.	50	6.		5,000	9	– –	YES	51	$1\frac{1}{16}$		1"-$\frac{3}{4}$" Wire	6, 46
		RLT2-27-1	165-220	48	55- 80		55 Min.	50	10.		1,000	9	– –	YES	17	$\frac{27}{32}$		1" Wire	6
		RLT2-27-1A	105-140	48	61- 80		55 Min.	50	3.		6,500	9	– –	YES	17	$\frac{27}{32}$		1" Wire	6
		SLT2-32-1	95-130		61- 80		55 Min.	50	3.		6,500	9	– –	YES	17	$1\frac{1}{16}$		1" Wire	
		T2-27-1R100	66- 74	48	52- 59		50 Min.	49	.5		10,000	9	– –	YES	41	$\frac{27}{32}$		1" Wire	52
		T2-27-1WR250	100-120	48	60- 70		55 Min.	50	2.5		5,000	9	– –	YES	41	$\frac{27}{32}$		1" Wire	52
		T2-27-1WR350	115-140	48	60- 70		55 Min.	50	2.5		5,000	9	– –	YES	41	$\frac{27}{32}$		1" Wire	52
		T2-27-1WR500	140-160	48	60- 70		55 Min.	50	3.		5,000	9	– –	YES	41	$\frac{27}{32}$		1" Wire	52
		T2-27-1WR760	170-200	48	60- 70		55 Min.	50	3.		5,000	9	– –	YES	41	$\frac{27}{32}$		1" Wire	52
		ST2-27-S	70- 78		55- 61		50 Min.	49	.5		15,000	35	– –	YES	19	$\frac{27}{32}$		1" Wire	53
		55ST2A	68- 75		56- 58		50 Min.	49	.5		15,000	35	– –	YES	19	$1\frac{1}{16}$		1" Wire	46, 53
		55ST2S	66- 76		52- 60		50 Min.	49	.5		15,000	35	– –	YES	19	$1\frac{1}{16}$		1" Wire	46, 53
		65ST2S	73- 78		61- 67		59 Min.	49	.3		25,000	35	– –	YES	19	$1\frac{1}{16}$		1" Wire	46
		70ST2S	100-120		64- 73		62 Min.	49	.3		25,000	35	– –	YES	19	$1\frac{1}{16}$		1" Wire	46
		90ST2S	94-106		77- 90		75 Min.	49	.3		5,000	35	– –	YES	19	$1\frac{1}{16}$		1" Wire	54, 46
		140ST2S	134-160		122-150		120 Min.	49	.3		25,000	35	– –	YES	19	$1\frac{1}{16}$		1" Wire	46
		A016	64- 80	59	– – –	59	– – – – – –		.3		7,500	55	– –	YES	57	$\frac{24}{32}$		1" Wire	5
		A051	205-250		– – –		– – – – – –		– –		– – –		– –	NO		$\frac{27}{32}$		1" Wire	58
		A057B	85 Max.	48	Avg. 60		– – – – – –		2.	56	10,000	55	– –	YES	17	1		1" Wire	6
		A059-2	65- 75		52- 53		– – – – – –		.3		7,500	55	– –	YES	57	$\frac{27}{32}$		1" Wire	6
		A059-3	65- 75		53- 54		– – – – – –		.3		7,500	55	– –	YES	57	$\frac{27}{32}$		1" Wire	6
		A059-4	65- 75		54- 55		– – – – – –		.3		7,500	55	– –	YES	57	$\frac{27}{32}$		1" Wire	6
		A059-5	65- 75		55- 56		– – – – – –		.3		7,500	55	– –	YES	57	$\frac{27}{32}$		1" Wire	6

		A059-6	65- 75		56- 57		------		.3		7,500	55	--	YES	57	27/32		1" Wire	6
		A059-7	65- 75		57- 58		------		.3		7,500	55	--	YES	57	27/32		1" Wire	6
		A059-8	65- 75		58- 59		------		.3		7,500	55	--	YES	57	27/32		1" Wire	6
		A059-9	65- 75		59- 60		------		.3		7,500	55	--	YES	57	27/32		1" Wire	6
		A074	85 Max.	48	50- 60		48 Min.		.3		10,000	55	--	YES	41	27/32		1" Wire	6
		A078	66- 74		50- 60		48 Min.		.3		10,000	55	--	YES	41	27/32		1" Wire	6
		A079	70 Max.		58 Max.		47 Min.		.3		7,500	55	--	YES	17	27/32		1" Wire	6
		A083	105 Max.	48	60- 70		58 Min.		2.		5,000	55	--	YES	41	27/32		1" Wire	6
		A089	SEL.NE2E		SEL.NE2E		------		.7		25,000	7	100K	NO		24/32		2" Wire	4
		A090	SEL.NE23		SEL.NE23		------		.3		6,000	2	--	NO		1 1/16		1" Wire	6
		A094	110 Max.		82- 86		------		.5-2.		20,000	7	--	YES	19	1 1/16		1" Wire	6, 46
		A094A	140 Max.		115-121		------		.2-2.		20,000	7	--	YES	19	1 1/16		1" Wire	6, 46
		HPG-27-1	140-160	48	60- 70		55 Min.	50	3.		6,000	9	--	YES	14	27/32		1" Wire	6
		A104	SEL.NE96		SEL.NE96		------		.5		3,000	12	--	NO		27/32		1" Wire	6, 15
		A106	190 Max.		129-133		------		5.2	61	20,000	7	--	YES	19	1 1/16		1" Wire	6, 46
		A110B	135 Max.		106-112		------		.2-.6		20,000	7	--	YES	19	1 1/16		1" Wire	6
		A219	100 Max.		---		------		2.		25,000	7	30K	YES	19	24/32		2" Wire	4, 6, 8, 60
		LPA-27-1					------		.3		7,500	7	--	YES	19	27/32		1" Wire	62
		HPN-27-1	175-220		<100		------		3.		2,000	7	--	YES	19	27/32		1" Wire	6

T2 Voltage Regulators

Indust. Number	Other	Breakdown Max. DC Volts	Initial Maintaining Volts DC mA	Voltage Variation From Initial Value Over Operating Range	Temperature Coefficient	Remarks
Z82R7		110	82±1 2.0 mA.	<1 volt from .25- 7.0 mA.	− 2 mV/°C	All regulators are compensated for dark effect and come with 1" wire leads.
Z82R10		115	82±1 2.0 mA.	<1 volt from .3 -10. mA.	− 2 mV/°C	
Z82R15	NU162/82*	118	82±1 2.0 mA.	<1 volt from .5 -15. mA.	− 2 mV/°C	
Z83R4	NU162/83*	110	83±1 1.5 mA.	<1 volt from .25- 4.2 mA.	− 2 mV/°C	
Z84R2	NU162/84*	110	84±1 1.0 mA.	<1 volt from .15- 2.0 mA.	− 2 mV/°C	The M.O.L. is $1\frac{1}{16}$" for glass parts and all have 12mm electrodes.
Z91R2		118	91±1 1.0 mA.	<1 volt from .1 - 2.0 mA.	− 3.5 mV/°C	
Z91R4		120	91±1 1.5 mA.	<1 volt from .2 - 4.0 mA.	− 3.5 mV/°C	
Z91R7		130	91±1 1.5 mA.	<1 volt from .25- 7.0 mA.	− 3.5 mV/°C	
Z91R10		135	91±1 1.5 mA.	<1 volt from .25-10. mA.	− 3.5 mV/°C	The light output from regulators is not usable as heavy sputtering is induced in the manufacturing process.
Z100R12		150	100±1 3.0 mA.	<1 volt from .6 -12. mA.	− 9 mV/°C	
Z103R2		130	103±1 .8 mA.	<1 volt from .2 - 2.0 mA.	− 4.5 mV/°C	
Z103R4		130	103±1 1.0 mA.	<1 volt from .2 - 4.0 mA.	− 4.5 mV/°C	
Z105R7		160	105±1 2.5 mA.	<1 volt from .6 - 7.0 mA.	− 9 mV/°C	
Z110R4		165	110±1 1.5 mA.	<1 volt from .5 - 4.0 mA.	− 9 mV/°C	
Z111R3		160	111±1 1.0 mA.	<1 volt from .5 - 3.3 mA.	− 9 mV/°C	Life expectancy is 20,000 hours for 103 volt regulators and up and 30,000 hours for the 82-100 V regulators.
Z115R4		150	115±1 .8 mA.	<1 volt from .15- 4.0 mA.	15 mV/°C	
Z115R7		155	115±1 1.5 mA.	<1 volt from .5 - 7.0 mA.	15 mV/°C	
Z116R2		145	116±1 .6 mA.	<1 volt from .12- 2.0 mA.	15 mV/°C	
Z133R6		230	133±3 .8 mA.	<1 volt from .8 - 4.8 mA.	−10 mV/°C	
Z139R1.5		185	139±3 .5 mA.	<1 volt from .3 - 1.9 mA.	−10 mV/°C	
Z143R1.5		220	143±3 .5 mA.	<1 volt from .3 - 1.9 mA.	−10 mV/°C	Life expectancy is based on original specifications.
V83R4		115	83±2 1.5 mA.	<2 volts from .25- 4.0 mA.	<15 mV/°C	
V84R2		115	84±2 1.0 mA.	<2 volts from .15- 2.0 mA.	<15 mV/°C	
V91R2		125	91±2 1.0 mA.	<2 volts from .1 - 2.0 mA.	<15 mV/°C	

V103R2		135	103±2	.8 mA.	<2 volts from .2 - 2.0 mA.	<15 mV/°C	*These types have a metal jacket and slightly different characteristics.
V110R4		170	110±2	1.5 mA.	<2 volts from .5 - 4.0 mA.	<15 mV/°C	
V115R4		155	115±2	.8 mA.	<2 volts from .15- 4.0 mA.	<15 mV/°C	
V116R2		150	116±2	.6 mA.	<2 volts from .12- 2.0 mA.	<15 mV/°C	
V139R1.9		190	139±4	.5 mA.	<2 volts from .3 - 1.9 mA.	<15 mV/°C	
V143R1.9		225	143±4	.5 mA.	<2 volts from .3 - 1.9 mA.	<15 mV/°C	

Notes

1 250K or more series resistance.
2 End of life is 5-volt change in breakdown or maintaining voltage.
3 Bulb tip marked with red lacquer.
4 Formed tip.
5 Dri-film coating.
6 Contains mild radioactive additive for the reduction of dark effect.
7 Based on ac operation.
8 High brightness.
9 Based on initial breakdown and maintaining voltages.
10 MOL $1^{11}/_{16}$"
11 Round end bulb.
12 End of life is 10-volt change in breakdown or maintaining voltage.
13 After 100 hours at design current.
14 Anode identified by blue dot.
15 Maximum diameter is .275".
16 100-volt maximum in total darkness.
17 Anode identified by green dot.
18 Based on 5-volt change in maintaining voltage.
19 Anode identified by red dot.
20 Anode identified by green dot.
21 Anode identified by white dot.
22 Lamp drops through .310" cylinder approximately 1" long.
23 Flat end bulb.
24 Not specified, but more than 99% are initially between 60-80 volts.
25 MOL $^{15}/_{16}$".
26 Outside acid frost.
27 Not specified, but more than 99% are initially between 50-75 volts.
28 Maximum breakdown in total darkness is 100 Vac.
29 MOL 1.030".
30 Based on 50% decrease in ultraviolet output.
31 Based on use as a film marker.
32 Argon filled.

Notes

33 Helium-argon filled.
34 Minimum design current is 1.5 mA.
35 Based on 6-volt change in maintaining voltage.
36 MOL 5/8".
37 MOL .938".
38 MOL .875".
39 Minimum differential voltage of 13 volts.
40 Maximum bulb diameter of .235".
41 Anode identified by black dot.
42 Leakage = 2.5×10^{-9} A at 45 Vdc, 25°C and 50% RH.
43 Approximate dc breakdown voltage after 100 hours at design current is 70 volts.
44 Pre-aged at 2.5 mA for 24 hours before selection to breakdown voltage.
45 Comes with resistor attached and can be any specified value ±20%.
46 Uses longer electrodes (12 mm).
47 Together with the D2A this has the highest light output of all the T2 lamps.
48 In total darkness.
49 Tested with 50K series resistor.
50 Tested with 5K series resistor.
51 Anode identified by short lead.
52 Electrodes contain small amounts of radioactive Ni63.
53 Additional specifications concerning vibration, shock and humidity are available from the manufacturer.
54 Emits blue-white light.
55 Based on 6-volt change in breakdown or maintaining voltage.
56 60 mA peak current.
57 Anode identified by orange dot.
58 Designed as a line voltage arc-suppressor. Life depends on energy transfer and duty cycle.
59 Lamps are categorized per 1-volt spread on both breakdown and maintaining voltage.
60 Pre-aged NE2U and selected for maximum breakdown.
61 Voltage regulation range is 0.45-5.2 mA.
62 Rapid deionization time.
63 Meets MIL-L-15098B specification for resistance to shock and vibration.
64 Internal resistor is included for 110-120 Vac operation.
65 Internal resistor is included for 210-250 Vac operation.
66 Meets MIL-E1-C specification for 991 regulator tube.
67 Center electrode connected to shell.
68 Outside spray-coated orange.
69 Outside spray-coated red.
70 Upper electrode connected to shell.
71 Black base.

TESTING GUIDELINES

A preliminary visual inspection under operating conditions can sometimes reveal useful information such as the type of gas, length of electrodes, and whether or not it is a high pressure type (small corona and widely-spaced electrodes).

It can also reveal defective conditions such as excessive sputtering, misaligned electrodes, arcing, and leaks. Normal indicator types, all of which use lower pressures, may be considered defective if the corona "jumps," or if it fails to cover ⅔ of the electrode. It may be worthwhile to note that even if an indicator electrode is completely covered but the corona is "soft" or "flowery," it is usually considered defective, because the life figures for these types are greatly reduced.

Electrical tests are, of course, performed by whatever instruments are available. Oscilloscopes, digital voltmeters, or electrometers can all be used to perform the same test and get nearly the same results, so rather than include detailed test procedures, a few overall guidelines are listed.

1. Try to test the lamp in the actual circuit.
2. Test instruments having a high input impedance are recommended. The 1-megohm oscilloscopes are satisfactory for static breakdown and maintaining voltage tests, but can disable an oscillator or other high-resistance circuit.
3. Breakdown voltages are affected by radiation fields, ambient light, the length of time it has been in the conducting state, and the speed with which the breakdown voltage is applied (ramp slope or rise time). The test conditions must be specified to make the test valid.
4. Specify the circuit resistance used in any extinguishing voltage test.
5. Shunt capacitance as small as 1 pF (scope probe), can cause parasitic oscillations when observing the high-resistance side of the lamp (over 1 megohm).
6. The dynamic differential voltage or peak-to-peak waveform of an oscillator is not the same as the dc differential voltage, so each should be tested in a different manner.
7. Ionization time tests should include risetime, or ramp

characteristics, plus the amplitude of the ionizing pulse.

8. High-pressure types are usually tested with, or monitored by, an oscilloscope, as the inherent noise spikes and voltage jumps cannot be easily recognized by voltmeters or counters.

When a quantity of neon lamps is to be tested, clip leads and soldered connections may, at times, be considered too slow. One solution is to use a transistor test socket such as the Pomona TS-187. Another solution is to make a test stand of plastic or bakelite and drill two vertical holes ⅛ inch in diameter and 2 inches deep. Fill the holes with mercury and contact the base of the mercury column with horizontal external screws. These screws are used for the electrical connections, and the mercury pools serve as the test socket. Still another method is to use two small magnets separated by a piece of plastic and secured to a board. The magnets not only serve as the electrical connection but they will hold the Dumet lamp leads.

SPECIFYING GUIDELINES

It is usually not necessary to use any one designation when ordering glow lamps from the manufacturer as he will furnish the correct component under its proper listing. If, however, the lamp is ordered from an electronic parts or wholesale house, the designation as listed in its catalog should be used.

Actually, specifications alone are all that are needed by most manufacturers, even for orders as small as 100 lamps. The user has only to keep in mind the basic limitations of the neon tube, such as the voltage and current capabilities. Maintaining voltages less than 45 volts and breakdown voltages in excess of 250 volts, for instance, are unrealistic, even though they are possible.

Perhaps the main reason that ordering by specification has become popular is that the users can include special tests that are of particular importance. Some common "specials" are wire leads several feet long, energy transfer test, lamp partially painted with reflective material, silver plated leads, guaranteed sawtooth amplitude at a particular frequency, and a guaranteed frequency of oscillation.

PRICING GUIDELINES

Each specification requested will add to the price of the lamp and if the specification is made tighter, the purchase price will be even higher.

Any additional steps in the manufacturing procedure will also increase costs. This includes welding, tinning, acid frosting, gauging, aging, encapsulating, and electrical testing.

The net price for an average regulator is around $1.60, while circuit components range from $ .10 to $ .45. The average net cost of a T2 indicator type (unbased) is about $ .08.

MOUNTING CONSIDERATIONS

Tip shapes and base terminals have some bearing on mounting methods used for neon lamps. Length of service and need for replacement are also factors to consider; that is, should it be a clamp or socket, for easy replacement, or can the lamp be cemented in a more permanent installation? Fig. 8-2 shows

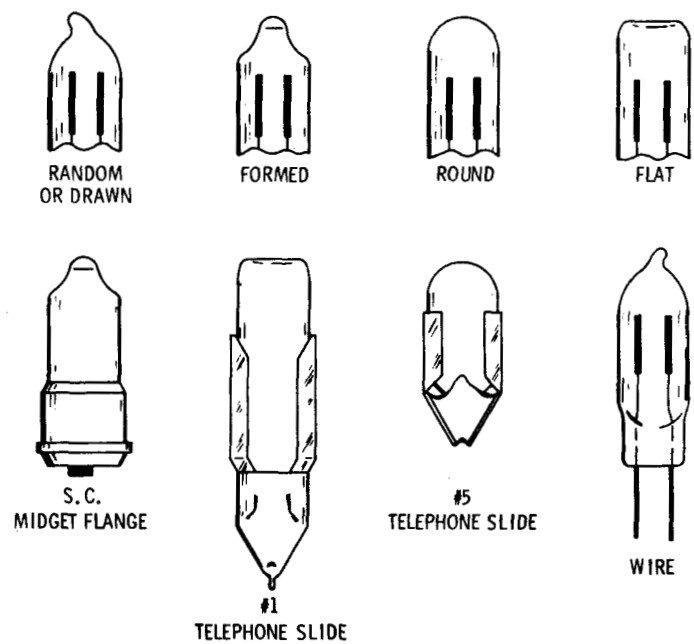


Fig. 8-2. Neon-lamp tips and bases.

tip shapes and basing construction of some miniature neon lamps. Fig. 8-3 shows several methods of mounting to a printed circuit board. Multiple mounting and panel mounting examples are shown in Fig. 8-4. One commercial neon lamp holder (Fig. 8-5) is designed to mount in a slot in a panel and includes a colored indicator lens.

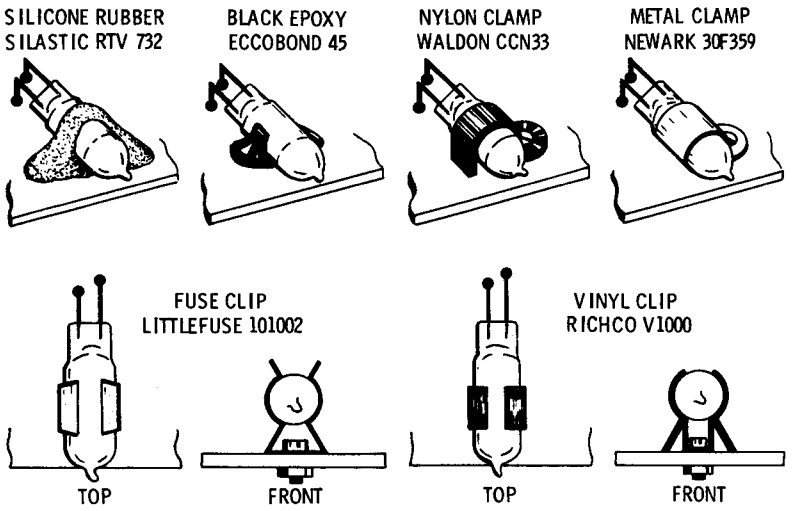


Fig. 8-3. Printed circuit board mountings.

T1 AND BALL-END LAMPS

Lamps Inc. manufactures three neon lamps with diameters of .125 in. All are the high-brightness type, pre-aged, and compensated for dark-effect.

USAS Type A1K is .250 in. long with 1 in. gold-plated leads.

USAS Type A1L has a sub-midget flange base with a MOL of .360 in.

Manufacturer's type 95BE is a special lamp that has a ball-shaped viewing end on the .125-in. shaft. This permits the lamp to be mounted directly in a panel hole and secured in the rear with an O-ring. This type of mounting is shown in Fig. 8-6. Mounting with a rubber grommet is also shown in the same figure. The 95BE has an MOL of .500 in. and comes with 1-in. gold-plated leads.

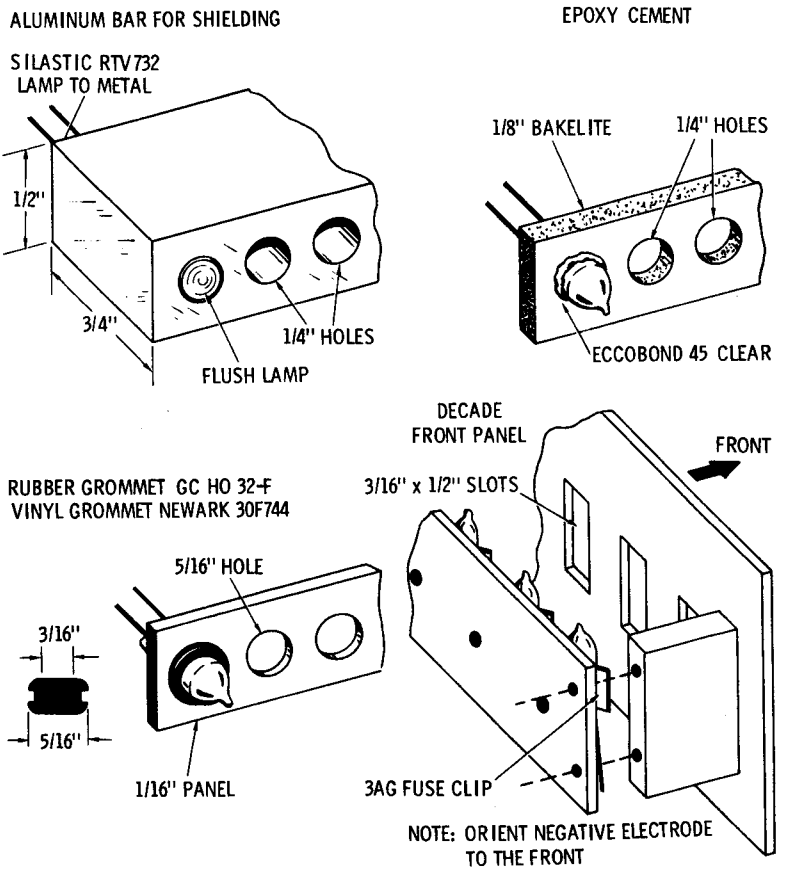


Fig. 8-4. Multiple and panel mountings.

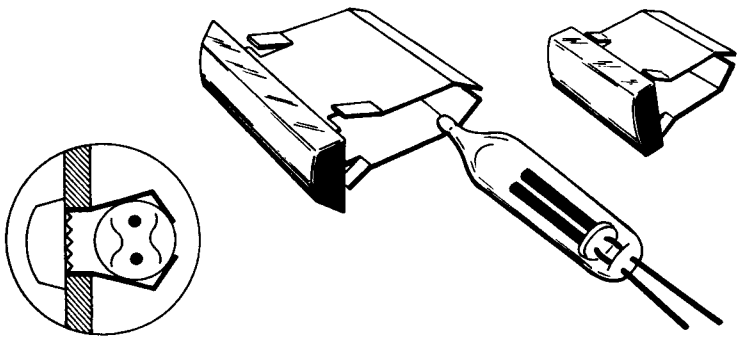


Fig. 8-5. A commercial neon-lamp mounting.

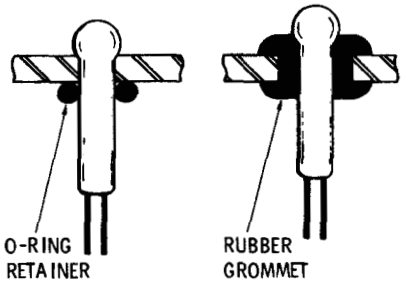


Fig. 8-6. Ball-end lamp mounting.

T1⅜ CRATER-ELECTRODE LAMPS

Alco Electronic Parts, Inc. offers two unbased lamps having 0.172 in. diameters and round tips. The crater or "bullseye" electrode is used in these types to increase the light output from the viewing end.

Manufacturer's Type MNE-4L comes with 10-inch insulated leads and type MNE-4 has short, untinned leads.

Appendix

USING THE NOMOGRAMS

The frequency nomograms in Figs. A-1, A-2, and A-3 show the relationship between the RC time constant, power supply voltages, and frequency.

If a straight line is connected between any two known values, the third or unknown value can be found along the same line.

Example: A one-lamp oscillator using a 10-meg resistor and a .001-μF capacitor is connected to a 175-volt power supply.

The frequency can be determined by extending a straight line on Fig. A-2 from 175 volts through time constant .01 (10,000,000 ohms $\times$ .000000001 farad), to the Hz scale.

(An RC time-constant nomogram is also included in this section for convenience.)

Answer: 600 Hz.

When the oscillator nomograms are used to find the needed time constant, then the chapter on oscillators should also be consulted, since there are minimum and maximum resistance values associated with each oscillator type.

The time constant for the astable multivibrator is calculated by multiplying the value of C in farads by the SUM of R1 and R2 in ohms. Equal values of resistance provide a symmetrical output.

The fourth nomogram (Fig. A-4), is an RC time-constant nomogram that is limited to the range and parts values normally encountered in gas tube oscillators.

Again, a straight line connected between any two known values will reveal the third or unknown quantity along the same line.

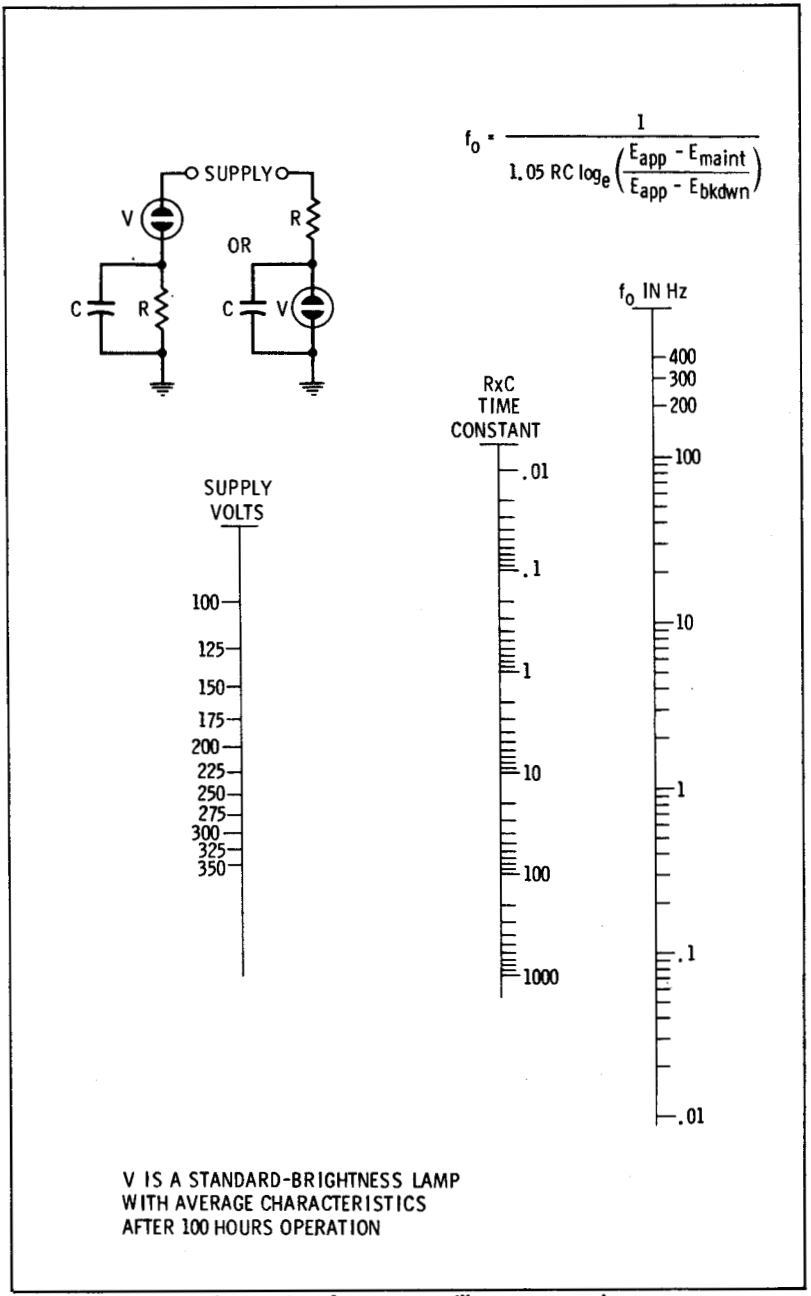


Fig. A-1. Low-frequency oscillator nomograph.

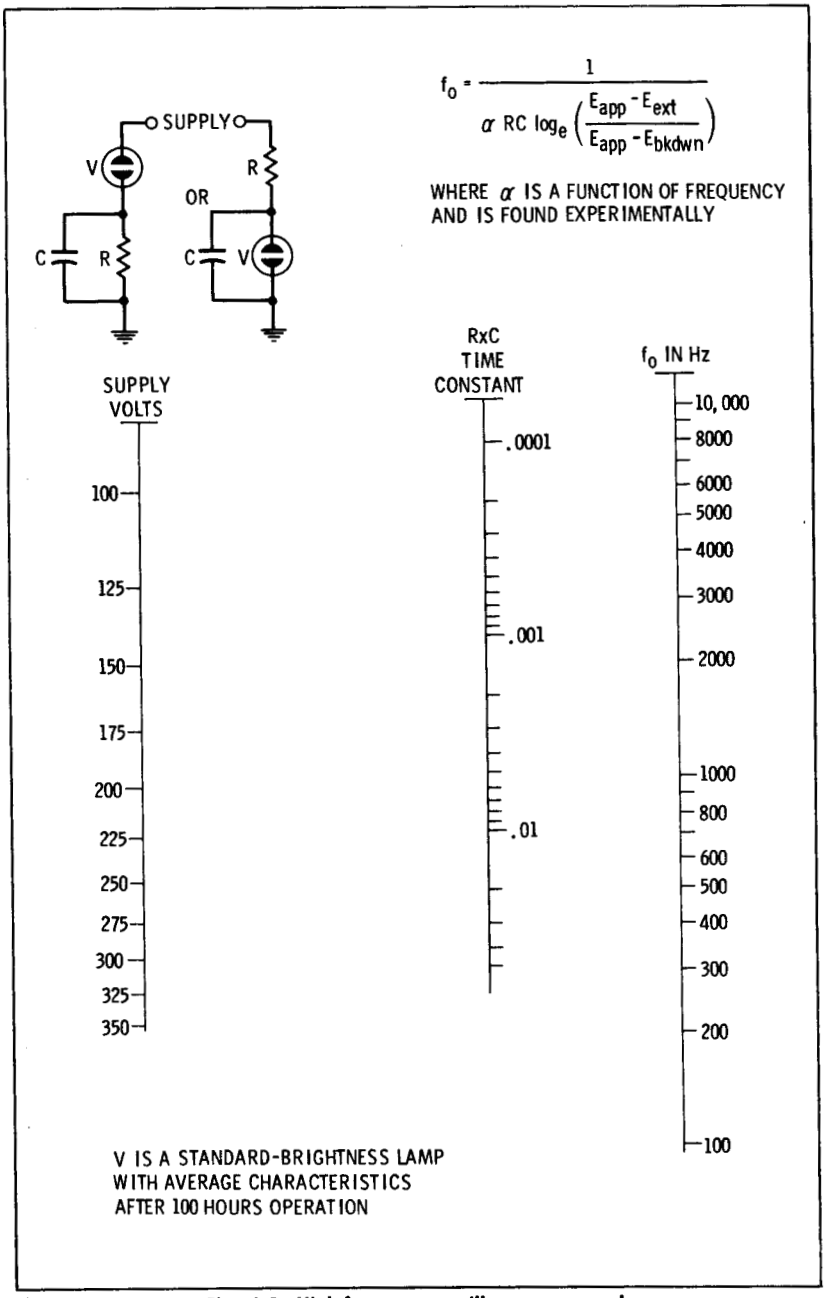


Fig. A-2. High-frequency oscillator nomograph.

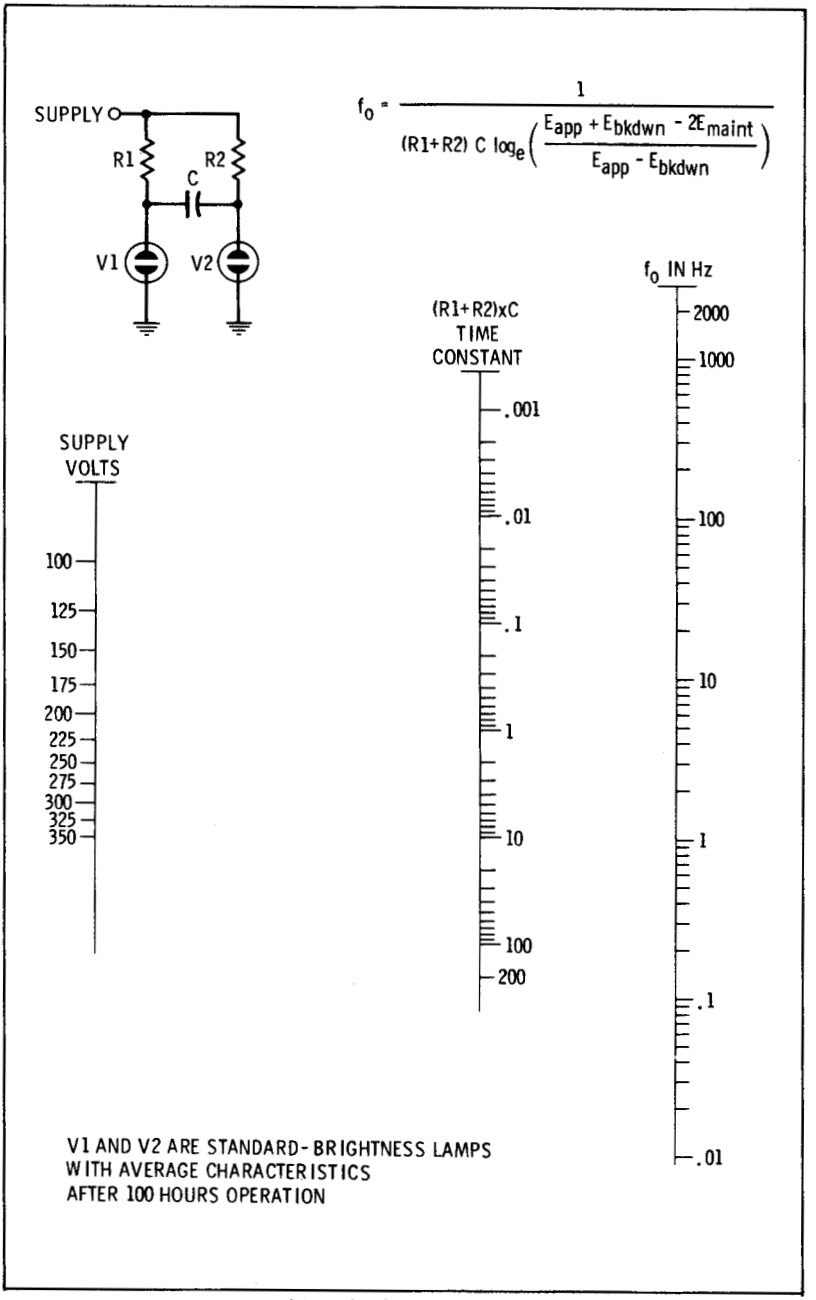


Fig. A-3. Astable-multivibrator frequency nomograph.

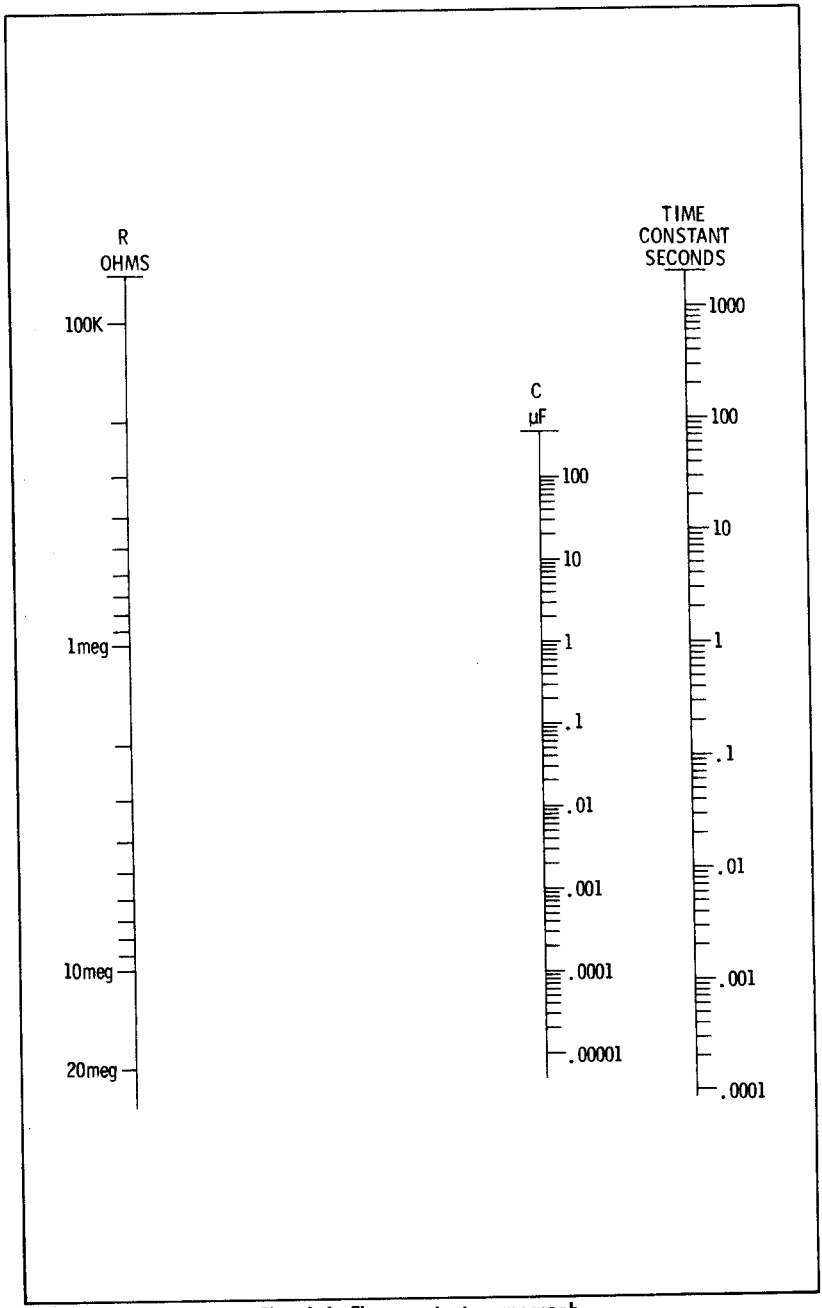


Fig. A-4. Time-constant nomograph.

Index

A

Abnormal glow, 10
Ac calibrator, 87
Aging
  procedures, 94-96
  process, 11
Algebraic addition of voltages, 33, 34
Alignment, radio, 91
Altitude, effect of, 16
Amplifier, sine-wave, 70
A-m signal generator, 90, 91
AND gate, 51-53
Antileakage coating, 94
Arc suppression, 76
Argon, 12
Arrester, lightning, 76, 77
Astable multivibrator, 43, 45, 68, 69
Audio
  output indicator, 24
  switch, 74, 75
Avalanche
  current, 8, 10
  time, 41

B

Ball-end lamps, 114
Barium, 13
Binary counter, 51
Bistable multivibrator, 49, 50, 74
Breakdown voltage, 8, 10
  static, 10
Brightness
  high, 16, 17
  standard, 16, 17
Burn-out, 15

C

Cadmium selenide, 66
Cadmium sulfide, 66
Calibrator
  ac, 87
  digital, 86
  voltage, 83-88
Capacitance of glow lamp, 93
Capacitive starting, 30, 33
Cascaded reference, 31
Cathode
  cold, 7
  sputtering, 26
Characteristic curve, of neon lamp, 9
Coating
  antileakage, 94
  of electrodes, 13
Cog-wheel effect, 62
Cold cathode, 7
Color of lamps, 16
Compensation for dark effect, 12
Construction of lamps, 17
Control
  SCR, 62
  touch, 74
Corona, 10
  jump, 42

Corona—cont'd
mode, 9
unstable, 13
Corotron, 9
Counter
binary, 51
ring, 54, 55
Crater electrode, 116
Current
avalanche, 8, 10
design, 11
run-away, 8
self-sustaining, 8

D

Dark effect, 11
compensation, 12
Darkening, 16
Decade ring counter, 56, 58
Deionization time, 10, 11, 55, 56
effect on oscillator frequency, 42
Delay
pulse, 75
time, 53
Design
current, 11
of regulator, 33
Differential voltage, 10, 54
reference, 32
Digital calibrator, 86
Diode isolation, 29

E

Efficiency of lamps, 15
Electrode
coating, 13
crater, 116
materials, 12
size, 13, 26
spacing, 13
End-of-life, 11
Extinguishing voltage, 10

F

Firing
potential, 10
resistor, 28
Flasher
neon, 43, 46, 47
random, 48
sequential, 47, 48
Flip-flop multivibrator, 49, 50
Foreign lamps, 17, 18
Frequency
doubling, with multivibrator, 46
limit of oscillator, 37, 42
of light radiated by gas lamps, 93
of multivibrator, 44
Fuse indicators, 22, 23

G

Gamma radiation, 13
Gas
lamp resistance, 7, 93, 94
pressure, 13, 42
tubes, series operation of, 29
Gate
AND, 51-53
MAJORITY, 52, 53
OR, 51, 52
Generator
a-m signal, 90, 91
high-amplitude sawtooth, 42
square-wave, 45
Glow
abnormal, 10
normal, 10

H

Helium, 12, 16
High
brightness, 16, 17
current regulator, 26, 31, 32
energy detection, 90
pressure gas, 42
Holding voltage, 10
Humidity sensor, 71

I

Incandescent lamp, 15
miniature, 15
Indicating lamps, 18-24
Indication, short-pulse, 21, 22

Indicator
audio output, 24
fuse, 22, 23
nonlatching, 20
Ion, 9
Ionization, 7-9
causes of, 10, 13
time, 10, 41
Isolation, by diode, 29

J

Junction devices, photoconductive, 71

K

Krypton, 12
Krypton 85, 12

L

Lamp
colors, 16
construction, 17
efficiencies, 15
incandescent, 15
neon, 15
defined, 15
Lamps, indicating, 18-24
Lamp, tungsten, 15, 16
Life of lamps, 17
Light, frequency radiated by gas lamps, 93
Lightning arrester, 76, 77
Light-operated threshold circuit, 69
Limiting resistor, 18

M

Maintaining voltage, 8
MAJORITY gate, 52, 53
Manley-Buckley ring counter, 54, 55
Memory circuit, 65, 66
Mercury vapor, 16
Miniature incandescent lamp, 15
Molybdenum, 12
Monostable multivibrator, 50, 51
Mounting neon lamps, 113, 114
Multivibrator
astable, 43, 45, 68, 69
bistable, 49, 50, 74
flip-flop, 49, 50
frequency of, 44
monostable, 50, 51
two-lamp, 43

N

Negative
resistance, 11
temperature coefficient, 13
Neon
flasher, 43, 46, 47
glow, color of, 12
Neon lamp, 15
characteristic curve, 9
defined, 7
other names, 7
specification chart, 100-110
Neon lamps
ball-end, 114
mounting, 113, 114
testing, 111
Neon-operated relay, 62, 63
Neon-regulated supply, 80
Nickel, 12
Nonlatching indicator, 20
Normal glow, 10
Numbering systems, 97

O

OR gate, 51, 52
Oscillation, relaxation, 19, 38
Oscillations, parasitic, 44, 54
Oscillator
frequency limit, 37
sawtooth, 38, 39
single lamp, 37
synchronized, 40, 41
triggering, 39
Overvoltage protection, 76-78

P

Parallel starting, 29

Parasitic oscillations, 44, 54
Photocell, 66, 67
Photochopper, 68, 69
Photoconductive junction devices, 71
Polarization, 12
Power line tester, 89
Power supply
  neon regulated, 80
  regulated, 79-83
  unregulated, 79, 80
Pressure of gas, 13
Pulse
  delay, variable, 75
  trigger, 39

R

Radiation, 13
  gamma, 13
  rf, 13
Radio alignment, 91
Random flasher, 48
Rectifiers, silicon controlled, 61
Reference
  cascaded, 31
  circuit, voltage, 27
  regulated, series-pass, 34, 35
Regulated
  power supplies, 79-83
  reference, series-pass, 34, 35
Regulation
  curve, 84
  series, 81
Regulator
  design, 33
  high-current, 26, 31, 32
  input voltage, 28
  load voltage, 28
  screen-grid, 34
  vacuum-tube, 79, 80
  voltage, general purpose, 28
Relaxation oscillation, 19, 38
Relay
  memory, 65, 66
  neon-lamp operation of, 62, 63
  threshold, 63, 64
  transistor driven, 64
Resistance
  negative, 11
  of gas lamps, 7, 93, 94
  series, calculation of, 27, 31, 36
Resistor
  firing, 28
  limiting, 18
  voltage-controlled, 68
Rf radiation, 13
Ring counter
  decade, 56, 58
  Manley-Buckley, 54, 55
Run-away current, 8

S

Sawtooth
  generator, high-amplitude, 42
  oscillator, 38, 39
SCR, 61
  control, 62
Screen-grid regulator, 34
Self-sustaining current, 8
Sensor
  humidity, 77
  temperature, 71
Sequential flasher, 47, 48
Series
  operation of gas tubes, 29
  regulation, 81
  resistance, calculation of, 27, 31, 36
  starting, 29
Series-pass regulated reference, 34, 35
Short-pulse indication, 21, 22
Shunt
  regulation, 81, 83
  starting, 29, 30
Silicon controlled rectifiers (see SCR)
Sine-wave
  amplifier, 70
  oscillator, 41
Single lamp oscillator, 37
Spacing of electrodes, 13
Specification chart, neon lamps, 100-110

Sputtering, 11
  cathode, 26
Square-wave generator, 45
Stabilization of gas lamps, 95
Standard brightness, 16, 17
Standing rise, 11
Starting
  capacitive, 30, 33
  parallel, 29
  series, 29
  shunt, 29, 30
Static breakdown voltage, 10
Striking voltage, 10
Strontium, 13
Switch, audio, 74, 75
Synchronized oscillator, 40, 41

T

Temperature
  effect of, 13
  sensor, 71
Tester, power line, 89
Tests for neon lamps, 111
Threshold
  circuit, light-operated, 69
  relay, 63, 64
Thyristor, 61
Timer circuits, 71-73
Touch control, 74
Townsend discharge, 10
Transient voltmeter, 88, 89
Transistor driven relay, 64
Trigger
  circuit, 39, 56, 57
  pulse, 39
Tungsten lamp, 15, 16
Two-lamp multivibrator, 43

U

Ultraviolet light, 12, 17
Unregulated power supply, 79, 80
Unstable corona, 13

V

Vacuum-tube regulators, 79, 80
Voltage
  algebraic addition of, 33, 34
  breakdown, 8, 10
  calibrators, 83-88
  differential, 10, 54
  extinguishing, 10
  holding, 10
  jump, 17, 42
  maintaining, 8
  reference circuit, 27
  reference, differential, 32
  regulator
    general purpose, 28
    input, 28
    load, 28
  striking, 10
Voltage-controlled resistor, 68
Voltmeter, transient, 88, 89

W

Work function, 12

X

Xenon, 12